

AMSAA

TECHNICAL REPORT NO. 293

SIMULATION AND ANALYSIS OF THE
TRAINING EFFECTIVENESS ANALYSIS-TOW (TEA-TOW)
FLIGHT DATA

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APRIL 1980

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AMSAA was requested to provide an independent third party analysis of TRADOC's Training Effectiveness Analysis-TOW (TEA-TOW) live firing data when neither the tester nor the TOW Program Manager's Office agreed on the cause of the large missile excursions and reduced frequency of hit. By making use of the AMSAA TOW missile simulation it is concluded that the missile excursions were the result of gunner tracking errors in all but one case. The excursions in flight 2407 are not the result of gunner tracking error.

In addition, these flight data are compared with the simulated trajectories

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20. ABSTRACT (CONT'D)

to demonstrate that the AMSAA TOW missile simulation is a valid representation of the real system especially when engaging the accelerating target.



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The contributions of the following individuals are acknowledged. Dr. Gerald Nielson recommended and calculated the spatial differences used to validate the simulation. Messrs. Arthur Gordon and Everett White conducted the simulations. The missile trajectory plots appearing in Appendix A were generated by Mr. Douglas Finley.

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SIMULATION AND ANALYSIS
OF THE TRAINING EFFECTIVENESS
ANALYSIS-TOW (TEA-TOW) FLIGHT DATA

1. INTRODUCTION

The purpose of this report is to analyze the TOW Training Effectiveness Analysis (TEA-TOW) flight data, and to validate the Army Materiel Systems Analysis Activity's (AMSAA) TOW missile simulation.

The TEA-TOW test program had been designed to measure the effectiveness of alternate TOW training programs. The first training alternative was the minimum phase wherein each trainee received eight hours of informal training. After this training period, each trainee fired one TOW missile (with an inert warhead) at a remotely controlled M47 tank. The tank moved at a constant velocity and was at a range of 2800 to 3000 meters. If the frequency of hit equalled the historic TOW frequency of hit, the program would be accepted. If not, another training program would be tried. The minimum program firings resulted in large missile excursions and unexpectedly low frequency of hit.

AMSAA was requested to provide an independent third party analysis of the TEA-TOW live firing data when neither the TOW Program Manager's Office nor the tester agreed on the cause of the large missile excursions and corresponding reduction in the frequency of hit. The tester, the Training Doctrine Command's (TRADOC) Combined Arms Training Activity (TCATA), blamed the anomalies on faulty missile guidance sets since several sets failed certain tests on the Land Combat Support System (LCSS) after the missile firings. Personnel from the TOW Program Manager's Office reviewed the video tapes of the firings and they concluded that the anomalies were the result of poor gunner tracking.

AMSAA proposed to solve the controversy with the methodology whereby measured gunner tracking error is used as the input to the TOW computer simulation and the resulting trajectory is compared to the actual trajectory. If reasonable agreement is obtained, the live-fire trajectories are attributed to gunner tracking error. If no agreement is obtained, the actual trajectory is probably due to faulty equipment since the missile is not following the gunner generated line-of-sight.

TCATA supplied AMSAA with the tracking error and

the time correlated trajectory data for 84 flights. After simulating these flights on the computer, only one simulated flight did not agree with the corresponding live-fire trajectory. Therefore it was concluded that the TEA-TOW missile trajectories were the result of gunner tracking errors.

Since the simulated and live-fire trajectories demonstrated qualitative agreement, the data were used to validate the TOW simulation in a more objective manner. In particular, these data were used to show that the simulation is valid against the so called "highly" evasive target. These are targets accelerating at $0.3g$'s (normalized gravitational units) or greater in a plane normal to the line-of-sight (LOS).

The validation of the simulation is an important outgrowth of this study since the validity of the simulation against the evasive target was questioned. The validation issue was very important to the success of the Armored Combat Vehicle Technology (ACVT) program. The ACVT program was willing to provide the funds for a field test so the data necessary to validate the simulation could be collected. Because of this analysis a considerable amount of money was saved by using existing data, rather than acquiring additional data, to verify the simulation.

2. PROCEDURES

2.1-Target Conditions

The target was a remotely controlled M47 tank moving at an average speed of 13.5 mph. The tank was moving at a 45 degree angle toward the gunner at a range of 2800 to 3000 meters. In all cases, the target was moving from the gunner's left to his right. This target speed resulted in a horizontal LOS rate of 1.5 mrad/sec and a vertical LOS rate of zero.

2.2-Data Acquisition

The tracking error and missile trajectory for each firing were recorded on video tape for post flight analysis. From these recordings, the tracking error and missile displacement were measured relative to the center of the target as a function of time. The tracking errors were measured in milliradians and the missile displacements were measured in feet. These values were measured 10 times a second to insure that the significant frequencies of the tracking error and missile displacements could be reproduced. These data were supplied to AMSAA on computer cards.

2.3-Tracking Error Analysis

For each of the tracking error time histories, the mean, variance and normalized power spectral density (PSD) function were obtained. These quantities were obtained by using an existing computer program, FTFREQ, from the International Mathematical and Statistical Libraries (Ref. 1). The mean and variance are computed by conventional means and the PSD function is obtained by taking the Fourier Transform of the autocorrelation function. The normalized PSD function is obtained by dividing the computed PSD function by the variance of the tracking error. These measures provide estimates of the amplitude and frequency content of the tracking errors. Additionally, pooled statistics such as the average of the means, standard deviations and normalized PSD functions were calculated to obtain the average performance of the TEA-TOW gunners.

2.4-Trajectory Simulation and Comparison

1. IMSL Library 3, Edition 6, 1977, Volume 1 of 2

The tracking error data were used as input to the TOW computer simulation along with target motion representative of a 1.5 mrad/sec constant velocity target. (TCATA indicated that perhaps 10 percent of the data were not constant velocity. However, the trial numbers of these runs were not recorded). In all cases, the target motion was simulated as moving from the gunner's left to his right.

The simulated trajectories were recorded on strip charts for "quick look" analysis and on digital magnetic tape for future processing. Since insufficient resolution was obtained with the strip charts, computer plots were made from the magnetic tape which allowed for a better comparison. Two computer plots were generated for each trajectory. One plot contained the actual and simulated trajectories in azimuth and the second plot contained the corresponding elevation trajectories. The trajectories were plotted from six seconds into the flight until target impact or, in the case of a miss, until the missile range equalled the target range. The data prior to six seconds were questionable since the first four seconds of the actual tracking data were usually missing and had to be fictitiously generated. The remaining two seconds appeared to be a reasonable settling time for the simulation to recover from the fictitious input. These computer plots were used to subjectively compare the actual and live fire trajectories.

2.5-Simulation Verification

The TEA-TOW data validated the simulation in a more quantitative manner. In particular, it shows that the simulation is a valid representation of the TOW missile system over a range of LOS inputs that include the LOS motion due to an accelerating target. This is possible since the input to the simulation and the actual missile is the LCS motion which is the total motion of the tracker. The LCS motion is made up of two components; gunner tracking error, TE, and target angular position, θ_t . This relationship and its first and second time derivatives are given in Equations 2.1 through 2.3.

$$\text{LOS} = \text{TE} + \theta_t \quad 2.1$$

$$\dot{\text{LOS}} = \dot{\text{TE}} + \dot{\theta}_t \quad 2.2$$

$$\ddot{\text{LOS}} = \ddot{\text{TE}} + \ddot{\theta}_t \quad 2.3$$

From Equation 2.3 it can be seen that large LOS

accelerations can be generated by large, oscillatory types of tracking errors even in the absence of accelerating targets, i.e. $\dot{\theta}_t \neq 0$. It is possible to obtain estimates of the LOS accelerations resulting from the tracking errors by using PSD techniques.

The output PSD, $PSD(W)_o$, of a system having a transfer function, $G(W)$, and input PSD, $PSD(W)_i$, is given by Equation 2.4.

$$PSD(W)_o = |G(W)|^2 PSD(W)_i \quad 2.4$$

In the frequency domain, the transfer function relating acceleration and position is

$$G(W) = -W^2 \quad 2.5$$

where W is angular frequency. Substituting for $|G(W)|^2$ in Equation 2.4 gives

$$PSD(W)_o = W^4 PSD(W)_i \quad 2.6$$

where $PSD(W)_o$ and $PSD(W)_i$ become the LOS acceleration and LCS position power spectral densities respectively. The integral of the acceleration PSD with respect to cyclic frequency, f , equals the variance of the LOS acceleration. This relationship is given in Equation 2.7.

$$\sigma_{acc}^2 = \int_0^{\infty} (2\pi f)^4 PSD(f)_i df \quad 2.7$$

Since an average normalized PSD function was obtained, Equation 2.7 becomes

$$\sigma_{acc}^2 = \sigma_{te}^2 \int_0^{\infty} (2\pi f)^4 PSD(f)_n df \quad 2.8$$

where σ_{te}^2 is the tracking error variance and $PSD(F)$ is the average normalized PSD function of the tracking error. In reality, the upper limit of integration in Equations 2.7 and 2.8 was set equal to the frequency where the amplitude of the $PSD(f)$ equalled 0.5 which is the half-power point of the

tracking error. Seventy-two percent of the tracking error variance is accounted for over this half-power bandwidth. Therefore, the effects of low amplitude, high frequency noise are eliminated from the acceleration calculation and only the significant frequencies and amplitudes of the tracking error are considered in the calculation of σ_{acc}^2 .

The live-fire and simulated trajectories were quantitatively compared by computing the average spatial differences between the corresponding trajectories. The average spatial difference is given by

$$\overline{SD} = \frac{\sum_{i=1}^n [(DY_i)^2 + (DZ_i)^2]^{1/2}}{n} \quad 2.9$$

where DY_i and DZ_i are the trajectory differences in azimuth and elevation at time t and n is the number of points per trajectory. For all of these flights, n is on the order of 80 since the time-of-flight considered in the analysis was from six seconds to about fourteen seconds. The spatial differences were plotted as a function of azimuth tracking error standard deviation in order to obtain an estimate of the goodness of the simulation as a function of the LOS input. The goodness of the simulation as a function of the LOS acceleration is obtained by making use of this figure and Equation 2.8.

The combination of the spatial differences and the subjective comparison of the trajectories provide confidence that the simulation is a valid representation of the TCW missile system.

3. RESULTS

3.1 Tracking Error Analysis

Table 3.1 presents the mean and standard deviation, in milliradians, of the azimuth and elevation tracking errors. The mean of the means is -0.061 mrad lagging in azimuth and 0.008 mrad high in elevation. The average standard deviation, which was computed by taking the square root of the average variance, is 0.257 mrad in azimuth and 0.070 mrad in elevation. This value of azimuth tracking error is 2.6 times larger than the standard deviation of trained gunners tracking the same target. Trained gunners will track this target with a standard deviation of 0.100 mrad in azimuth. The elevation tracking error is about what is expected of trained gunners yet when coupled with the azimuth tracking error it is smaller than expected. Past experience gained with TOW tracking errors indicate that trained gunners will have elevation tracking error amplitudes that are about 60 percent of the azimuth tracking error.

The normalized PSD functions of the azimuth and elevation tracking errors are given in Figures 3.1 and 3.2, respectively. The accuracy of these estimates is on the order of 15 percent at the 95 percent confidence level. The bandwidth or half-power point of these signals is between 0.6 and 0.7 Hz in azimuth and 0.5 Hz in elevation. The peaks in the PSD functions occur at 0.2 Hz in azimuth and 0.1 Hz in elevation. These bandwidths and peaks are consistent with tracking data analyzed in the past.

In accordance with Equation 2.8, the average variance of the LOS acceleration is computed to be $2.7 \text{ mrad}^2/\text{sec}^4$. The corresponding standard deviation of the acceleration is $1.6 \text{ mrad}/\text{sec}^2$. If targets were providing this LOS motion, they would have to be accelerating at peak levels of about $1.4g$'s at a range of 2.85 km . This level of acceleration is greater than the acceleration capability of a ground vehicle. Therefore, on the average, the angular accelerations resulting from these tracking errors are greater than those generated by evasive or maneuvering targets.

3.2 Trajectory Comparison

Computer plots of 84 missile trajectories are contained in Appendix A. These data were used to qualitatively compare the live-fire and simulated trajectories. Supplementing Appendix A are Table 3.2 and

Figure 3.3 which present the spatial differences and distribution of these differences of 80 flights. The four flights not contained in the data are 1119, 1150, 1241 and 1337. Flights 1119, 1150 and 1241 were removed from the table because they had a limited amount of live-fire data but the live-fire data that exist compare favorably with the simulated trajectories. Flight 1337 was removed because the simulated trajectory apparently exceeded the look-angle thereby causing a break in the guidance link. The look-angle is the angle between the tracker and the missile flare. This phenomenon rarely occurs, but, when it does, it is the result of high frequency noise being present in the missile system.

A review of the computer plots, Table 3.2 and Figure 3.3 indicate that flight 2407 does not agree with the corresponding live-fire elevation trajectory. The live-fire elevation trajectory is flying erratically below the intended LOS. Additionally, the spatial difference for this flight is 13.3 feet. A review of the trajectory plots indicates that this is the only live-fire trajectory that does not demonstrate reasonable agreement with the simulated flight. The actual flight 2407 was attributed to possibly faulty equipment.

The spatial differences of the 79 remaining flights are plotted as a function of the azimuth tracking error standard deviation and are given in Figure 3.4. There is a trend in these data that shows an exponential relationship between the spatial differences and the tracking error. This relationship is more pronounced if seven flights are removed from the data. These flights are 1143, 1152, 1201, 1206, 1217, 1304 and 1362. A review of the trajectory plots of these seven flights shows that the larger spatial differences are the result of biases in all of the flights except 1143 and 1304. Flight 1143 exhibits a live-fire elevation excursion of 5.0 to 7.0 feet near the end of the flight which is not apparent in the simulated trajectory. Flight 1304 exhibits a large spatial difference of nearly 5.0 feet with smaller than average tracking errors. This is the result of the actual missile still recovering from tracking error transients that occurred earlier in the flight.

A review of Figure 3.4 shows that the average spatial differences between the real missile and the simulation are about 2.0 feet for tracking error standard deviations of 0.200 mrad or less and exponentially increasing for larger tracking errors. It is shown in the next section that the larger spatial differences are due to

LOS motions forcing the missile to its acceleration limits.

TABLE 3.1. TRACKING ERROR STATISTICS

FLIGHT	AZIMUTH		ELEVATION	
	MEAN	SIGMA	MEAN	SIGMA
0	-.1669	.1530	.0195	.0762
1109	-.0248	.1068	.0406	.0707
1117	-.1392	.1140	.1591	.0490
1118	-.0685	.1221	.1611	.0458
1121	.0980	.3041	.0363	.1030
1122	.0377	.2211	-.0435	.0458
1124	-.2065	.1221	.1373	.0954
1127	-.1814	.1476	-.0245	.0400
1128	-.1192	.1480	-.0849	.0436
1129	-.1175	.1578	-.1117	.0200
1130	-.0641	.1619	.0041	.0656
1131	-.1640	.1841	-.0393	.0469
1135	.0315	.2249	.1281	.0480
1136	-.1622	.2195	-.0027	.0872
1137	.0691	.1526	-.0143	.0500
1138	.0080	.1761	.1273	.0332
1139	-.0611	.1897	-.0339	.0332
1140	-.0588	.2642	.0488	.0663
1142	-.1918	.1533	-.1121	.0714
1143	-.0009	.1673	-.0480	.0889
1144	-.1513	.1175	-.1128	.0529
1145	-.1170	.1183	.2302	.0566
1146	.2439	.1652	-.0333	.0608
1151	-.2531	.2841	-.2157	.0346
1152	-.4777	.2304	-.4419	.0200
1153	-.0264	.1327	.0917	.0632
1154	.0007	.1371	.0178	.0510
1155	-.1869	.1393	-.0050	.0608
1156	-.2727	.1606	-.0684	.0548
1157	-.1281	.1010	.1417	.0755
1158	.0019	.1421	.2505	.0781
1159	-.1768	.1192	.0516	.0400
1201	-.5490	.2112	.4597	.0592
1203	.0585	.3464	-.2062	.0721
1204	.4339	.3762	.4399	.0922
1206	.0534	.1975	.4308	.0678
1210	-.0381	.3081	-.0971	.1304
1212	-.1587	.2202	.1532	.0592
1217	.0448	.1910	.4580	.0316
1234	-.0171	.5442	.0561	.1428
1235	-.1749	.2865	-.1029	.0447
1236	.3404	.3782	-.0399	.0714
1237	.3644	.3887	-.0590	.0500
1239	.0361	.1868	.0560	.0539
1240	.2579	.3464	.0180	.0927
1241	-.4226	.6054	-.0991	.0707
1304	-.0586	.1428	.0190	.0400

TABLE 3.1. TRACKING ERROR STATISTICS (Continued)

FLIGHT	AZIMUTH		ELEVATION	
	MEAN	SIGMA	MEAN	SIGMA
1314	-.2197	.1490	-.1167	.0332
1317	.0697	.2066	.0742	.0574
1318	-.1563	.1229	-.0186	.0574
1324	-.0525	.1992	.0853	.0400
1327	-.0929	.2095	-.1405	.0200
1336	-.1481	.1407	.0661	.0300
1338	-.0165	.1546	-.0786	.0616
1339	-.1661	.2447	.0715	.0361
1340	.0241	.1349	-.0213	.0387
1342	-.3222	.3341	.0033	.0735
1360	.0185	.1345	-.0891	.0800
1361	.0527	.1703	-.0349	.0424
1362	.3925	.1105	-.0845	.0510
1370	.0994	.3764	-.1211	.0656
2407	.2231	.2126	.0096	.0557
2409	-.0634	.2579	-.0503	.0447
2410	-.1608	.1389	.0373	.0640
2412	-.1123	.3750	-.1300	.2147
2413	-.0818	.1732	-.0867	.0574
2428	.0409	.1849	-.0134	.0436
2434	-.0076	.1323	-.1221	.0469
2435	-.0549	.9608	-.0006	.2064
2436	-.0843	.2587	.0720	.0510
2437	-.1546	.1594	-.0555	.0300
2438	-.2233	.1513	.0522	.0480
2441	-.0554	.2076	.0160	.0775
2442	.0980	.2646	.0321	.0721
2446	-.3256	.4712	-.1517	.1039
2447	-.1733	.1830	-.0389	.0700
2449	.2381	.3028	-.0754	.0520
2451	-.1767	.1942	.1010	.0539
2453	-.2624	.2366	-.1303	.0436
2454	-.2251	.2345	-.0957	.0412
2457	-.0231	.1513	-.0538	.0346
POOLED STATISTICS				
MEAN	-.0612	.2566	.0080	.0698
SIGMA	.1765	---	.1439	---

TABLE 3.2. SPATIAL DIFFERENCES BETWEEN TRAJECTORIES

FLIGHT	AVERAGE SPATIAL DIFFERENCE	FLIGHT	AVERAGE SPATIAL DIFFERENCE
0	1.52	1235	2.85
1109	1.63	1236	2.86
1117	1.60	1237	5.48
1118	1.68	1239	2.66
1121	2.63	1240	5.38
1122	1.94	1304	4.84
1124	1.96	1314	1.59
1127	1.80	1317	2.13
1128	1.64	1318	1.75
1129	1.72	1324	1.38
1130	1.26	1327	2.09
1131	2.53	1336	1.41
1135	2.65	1338	2.00
1136	1.54	1339	1.92
1137	2.36	1340	2.21
1138	2.45	1342	4.16
1139	2.21	1360	1.13
1140	2.22	1361	1.69
1142	2.30	1362	2.70
1143	3.23	1370	2.43
1144	1.51	2407	13.23
1145	1.76	2409	3.30
1146	1.68	2410	1.76
1151	2.24	2412	7.55
1152	3.33	2413	2.21
1153	1.77	2428	2.39
1154	2.00	2434	1.26
1155	2.04	2435	7.75
1156	1.58	2436	2.78
1157	1.71	2437	1.67
1158	1.97	2438	2.00
1159	1.11	2441	1.89
1201	5.32	2442	2.70
1203	4.37	2446	5.79
1204	6.35	2447	2.61
1206	4.13	2449	4.48
1210	3.33	2451	1.87
1212	2.34	2453	1.49
1217	4.37	2454	2.83
1234	3.72	2457	1.63

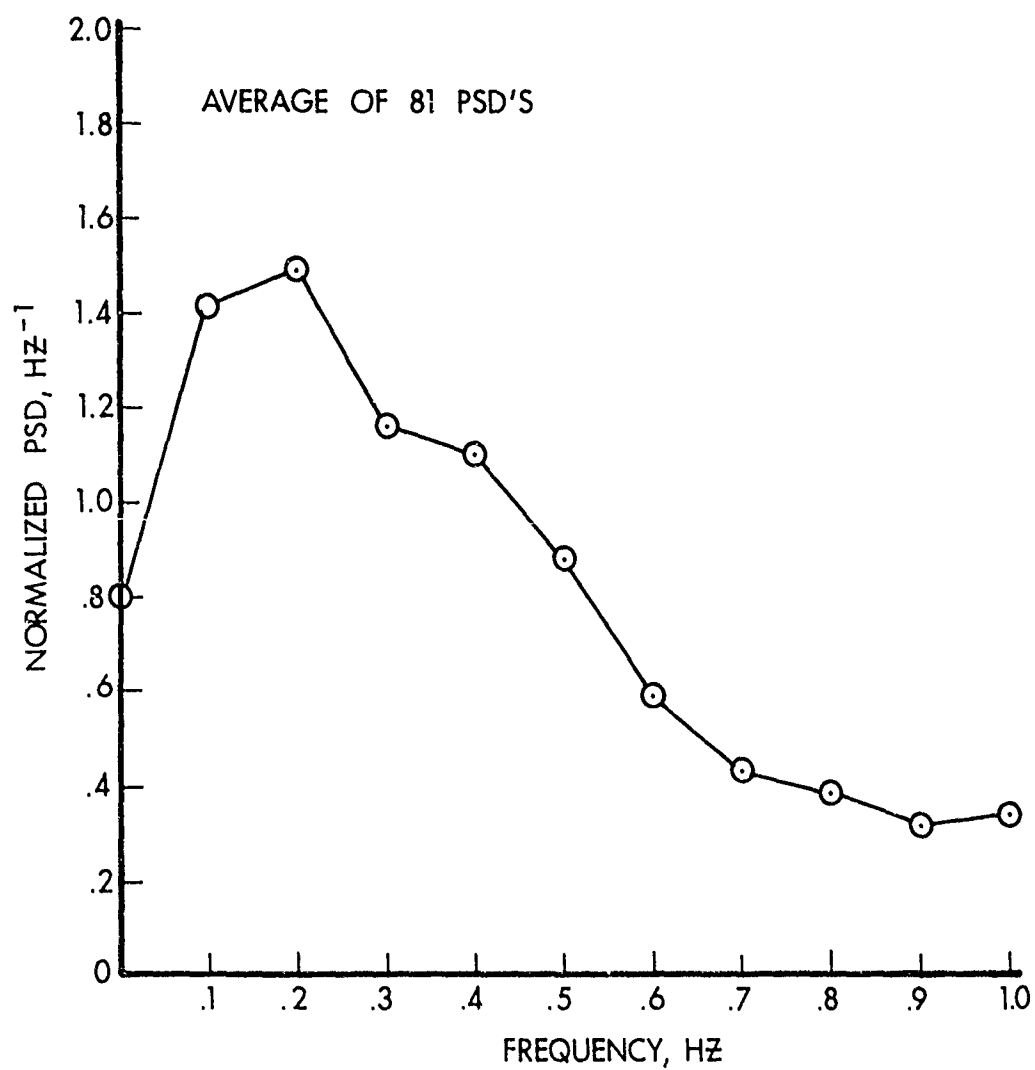


Figure 3.1 Azimuth Tracking Error Normalized Power Spectral Density.

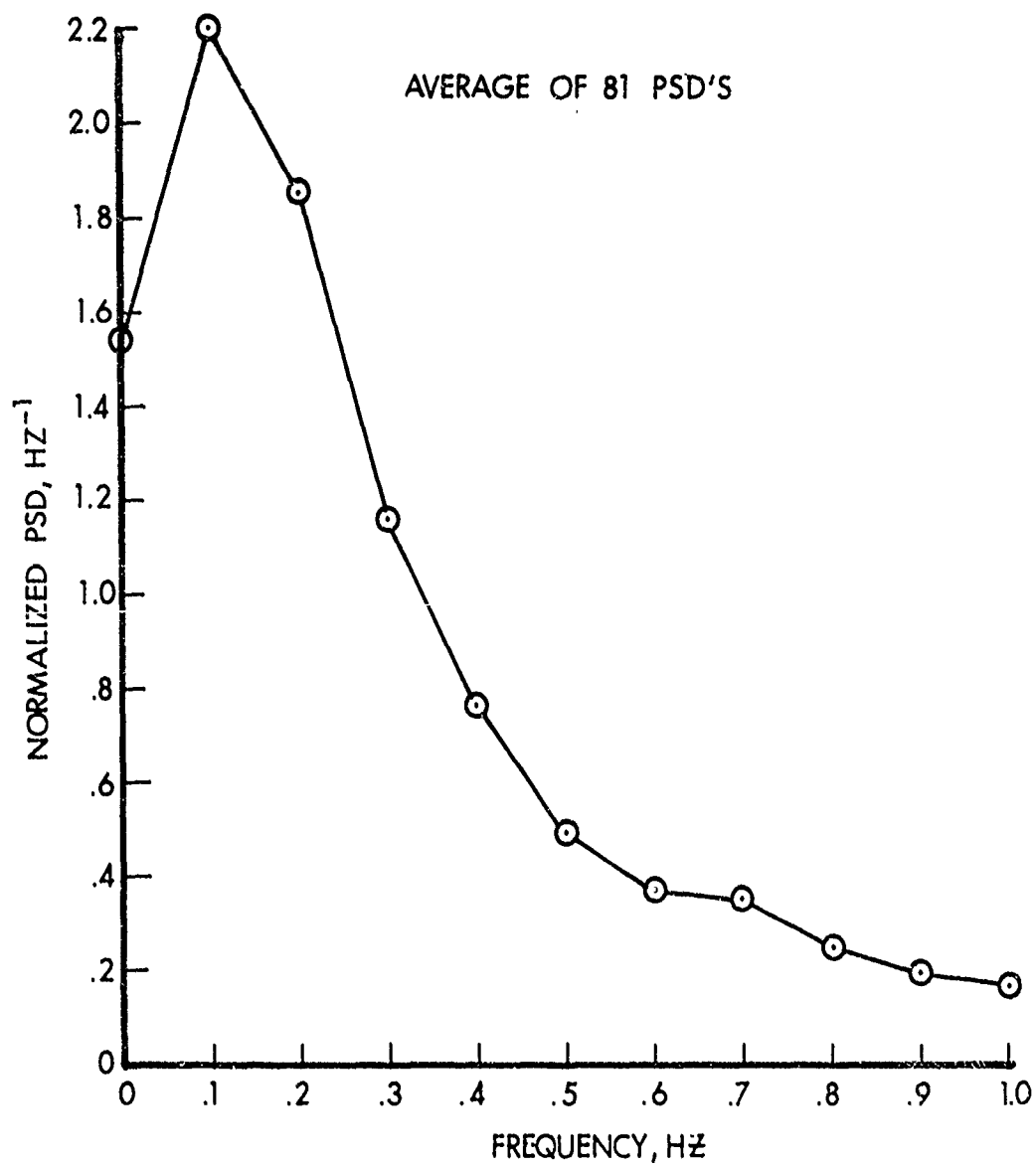


Figure 3.2 Elevation Tracking Error Normalized Power Spectral Density.

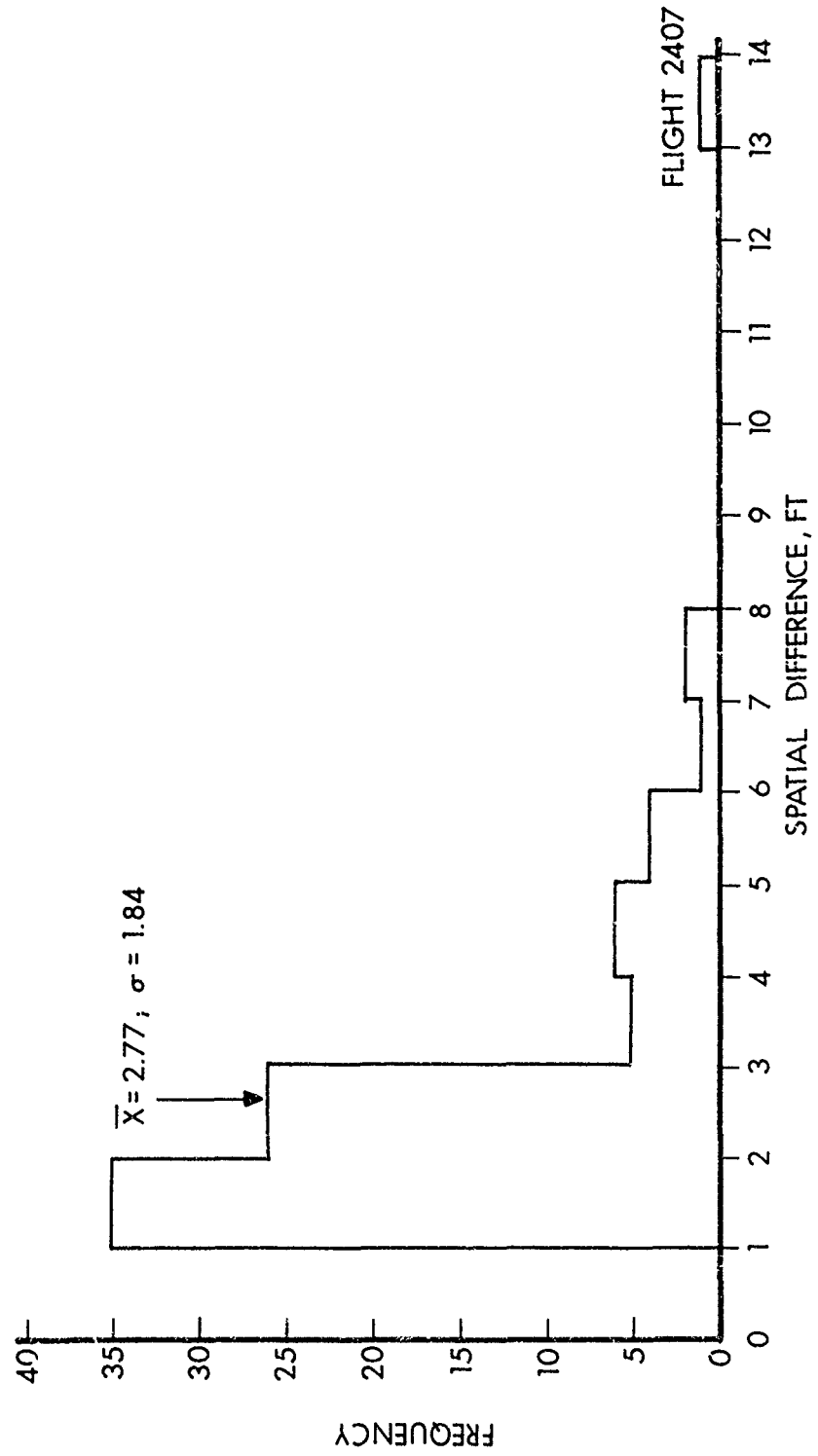


Figure 3.3 Frequency Distribution of the Spatial Difference.

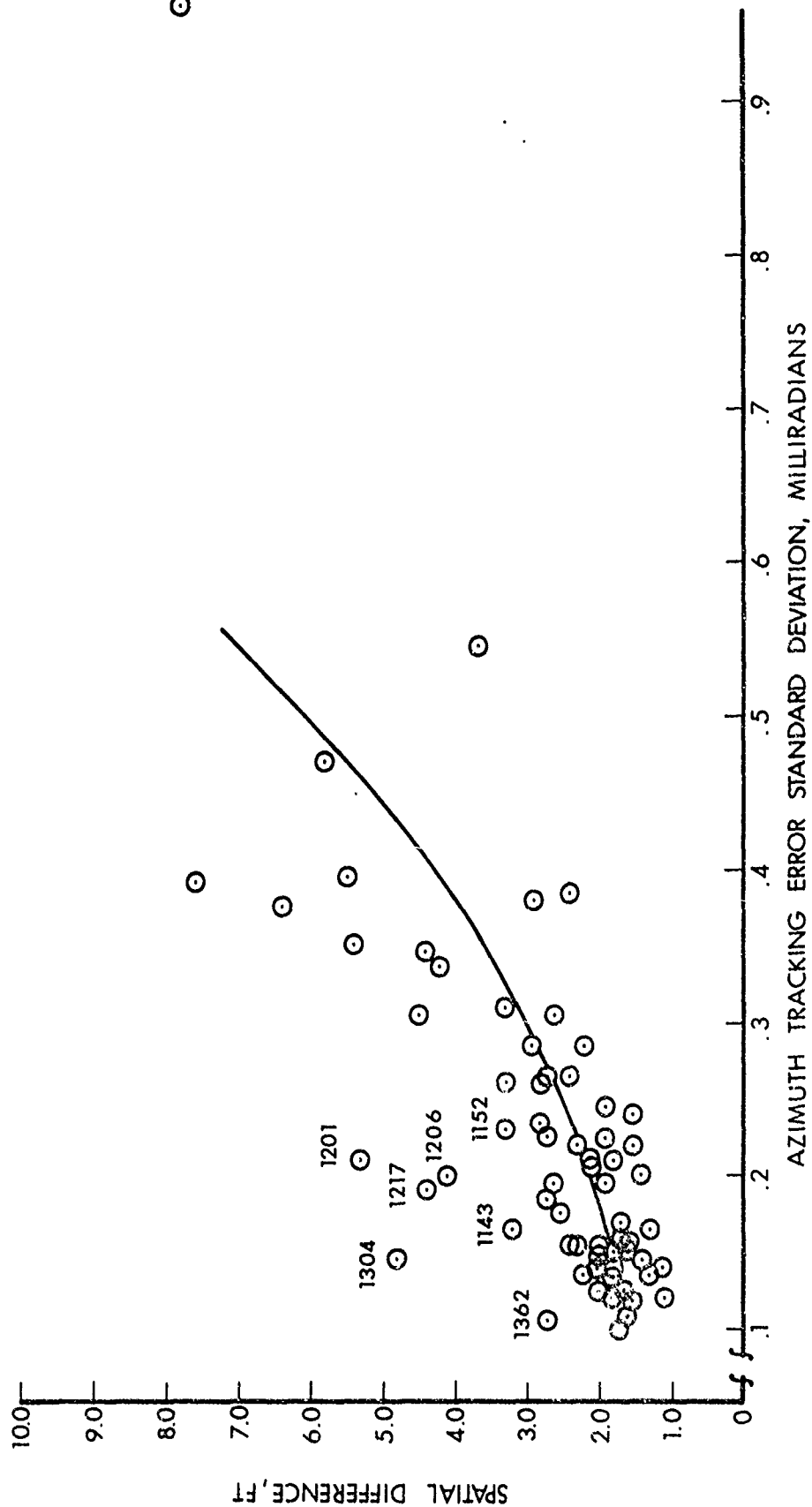


Figure 3.4 Spatial Differences vs Azimuth Tracking Error.

4. DISCUSSION

The overall results of this study show that the missile trajectories of the TEA-TOW program are the result of gunner tracking errors except flight 2407 which does not follow the gunner tracking error. A more important result of this study is the agreement demonstrated between the AMSAA TOW missile simulation and the actual system. It is shown in Figure 3.4 that the spatial differences are on the order of 2.0 feet for tracking errors below 0.200 mrad. These differences can be attributed to the following: (a) measurement errors in the tracking error and live-fire trajectory data (b) differences in the off-nominal conditions between the real system and the simulation (c) the actual missile still recovering from tracking error transients earlier in the flight and (d) modeling errors.

For tracking errors beyond 0.200 mrad, the spatial differences show increasingly larger values. By making use of Equation 2.8, it can be shown that these differences are the result of the larger oscillatory tracking errors requiring missile accelerations that are not available if the missile is to follow the LOS. Using Figure 3.1 and Equation 2.8, and assuming all gunners exhibit a PSD equivalent to the average PSD, the resulting average standard deviation of the LOS acceleration is

$$\sigma_{acc} = \sigma_{te} \left[\int_0^{\infty} (2\pi f)^4 \text{PSD}(f)_n df \right]^{1/2} \quad 4.1$$

Evaluating this integral, using Simpson's rule, over a bandwidth of .65 HZ, gives

$$\sigma_{acc} = 5.7\sigma_{te} \quad 4.2$$

The lateral missile motion required to follow the LOS motion is given by

$$Y_m = R_m \sin \text{LOS} \quad 4.3$$

where R_m is the missile range. Successively differentiating Equation 4.3 and using small angle approximations give

$$\dot{Y}_m \approx \dot{R}_m \text{LOS} + R_m \dot{\text{LOS}} \quad 4.4$$

and

$$\ddot{Y}_m \approx \ddot{R}_m \text{LOS} + 2\dot{R}_m \dot{\text{LOS}} + R_m \ddot{\text{LOS}} - R_m \text{LOS} \dot{\text{LOS}}^2 \quad 4.5$$

Assuming that

$$\ddot{R}_m = 0 \quad 4.6$$

and for this example

$$R_m \ddot{\text{LOS}} \gg 2\dot{R}_m \dot{\text{LOS}} - R_m \text{LOS} \dot{\text{LOS}}^2 \quad 4.7$$

Equation 4.5 is reduced to

$$\ddot{Y}_m = R_m \ddot{\text{LOS}} \quad 4.8$$

From Equation 4.8, it can be seen that the maximum required missile acceleration will occur when the missile is near the target provided the LOS acceleration exhibits stationarity in a statistical sense. By combining Equations 4.8 and 4.2, the peak missile acceleration required to follow the LOS resulting from the tracking error is given by

$$\ddot{Y}_m = 3(5.7\sigma_{\text{te}})(2.85) \quad 4.9$$

where $3(5.7\sigma_{\text{te}})$ is the 3-sigma or peak value of the LOS angular acceleration in mrad/sec and 2.85 is the target range in kilometers.

The maximum lateral acceleration capability of the missile is shown in Figure 4.1, as a function of range. At a target range near 3.0 km, the maximum available missile acceleration is just over 1.0g. Substituting this value of acceleration into Equation 4.9 and solving for the tracking error standard deviation, gives the value of the tracking error standard deviation which forces the maximum acceleration capability of the missile. This value is 0.200 mrad which is where the larger spatial differences start occurring in Figure 3.4. However, there are several flights which still show reasonable spatial differences above this

value.

These results imply that the simulation is a valid representation of the TOW missile system up to, and in some cases beyond, the point where the LOS inputs are such that the maximum available missile acceleration is required. In terms of validity against maneuvering targets, the results indicate that the missile simulation is valid against targets accelerating up to the acceleration limits of the missile provided the gunner tracking errors are small. This level of acceleration is greater than the acceleration capability of a landborne vehicle.

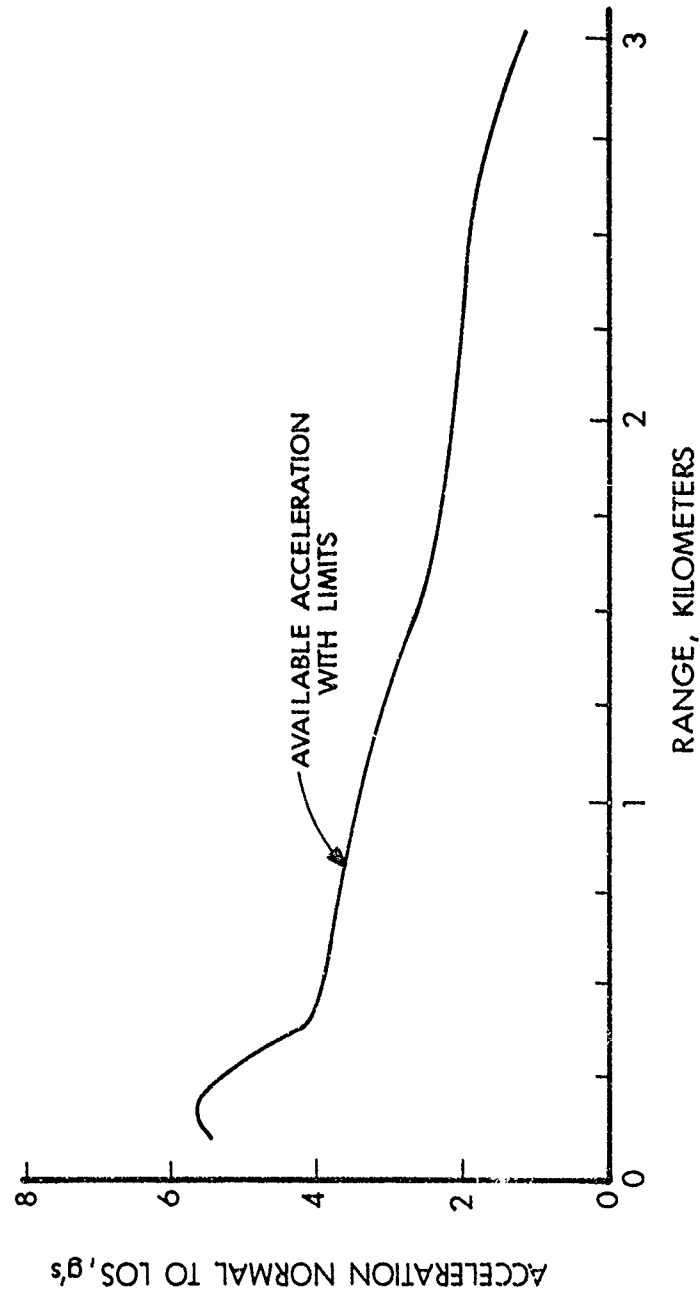


Figure 4.1 TOW/Infantry Missile Acceleration Capability (Azimuth)

*(SUPPLIED BY HUGHES AIRCRAFT COMPANY)

5. CONCLUSIONS

The results of this study show that all but one of the TEA-TOW flights followed the gunners' tracking error. The live-fire trajectory of trial 2407 is not following the gunner tracking error and may be the result of faulty equipment.

The average azimuth tracking errors are 2.6 times larger than the average performance of trained gunners tracking the target angular rates presented. The elevation tracking errors are about the same as those of trained gunners but are smaller than expected since the elevation tracking error is usually 60 percent of the azimuth tracking error. The TEA-TOW elevation tracking errors are about 30 percent of the azimuth tracking error. It is therefore concluded that adoption of the minimum training program, such as that tested, would result in a degradation in TOW performance over that which could be achieved with the full training program.

From both a quantitative and qualitative analysis it is shown that the AMSAA TOW missile simulation is valid over a wide range of LOS inputs. In terms of accelerating targets, the simulation is a valid representation of the actual missile system and is capable of providing reliable performance estimates against targets accelerating up to 1.0g at a range of 2.85 km.

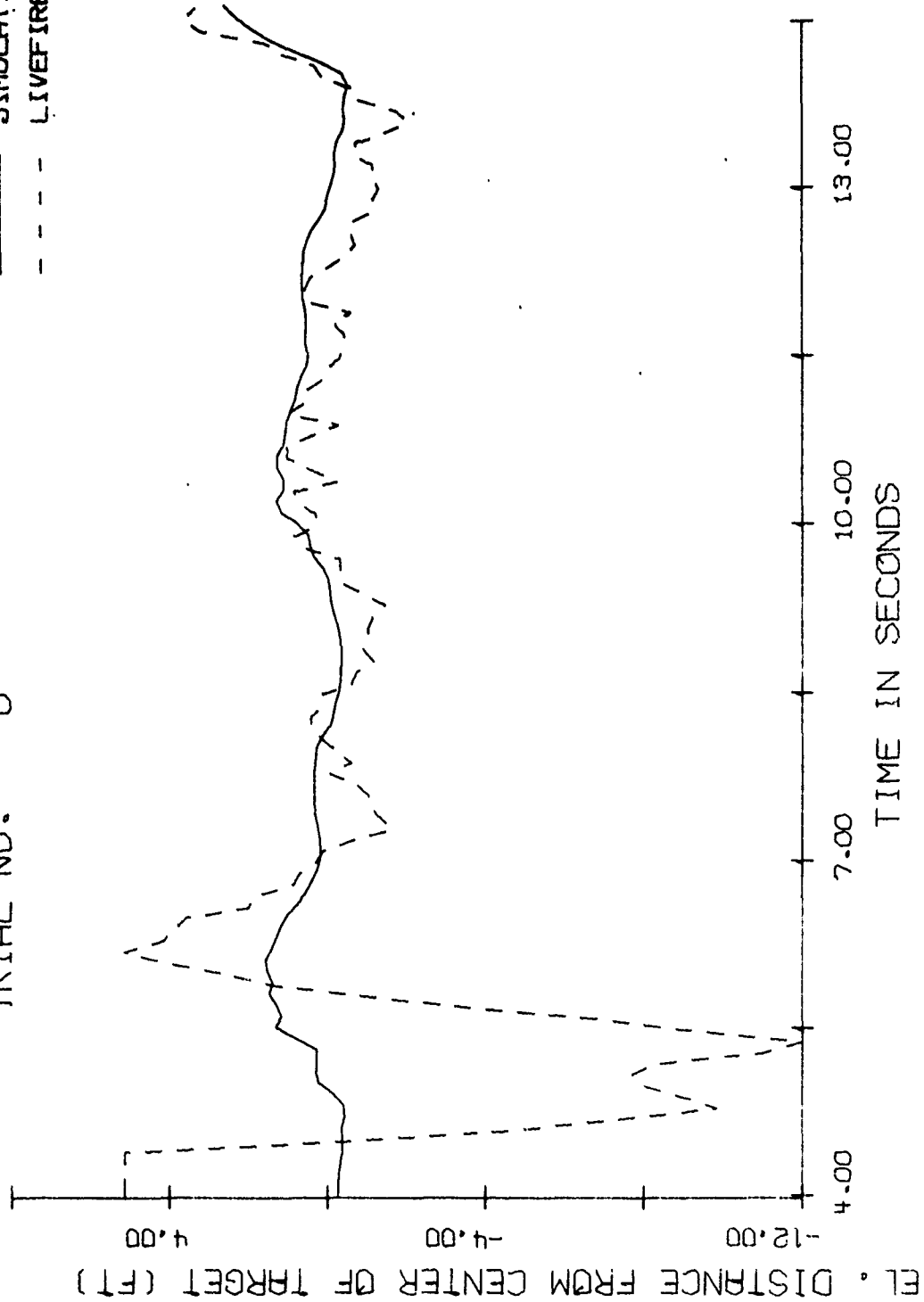
APPENDIX A

A-1

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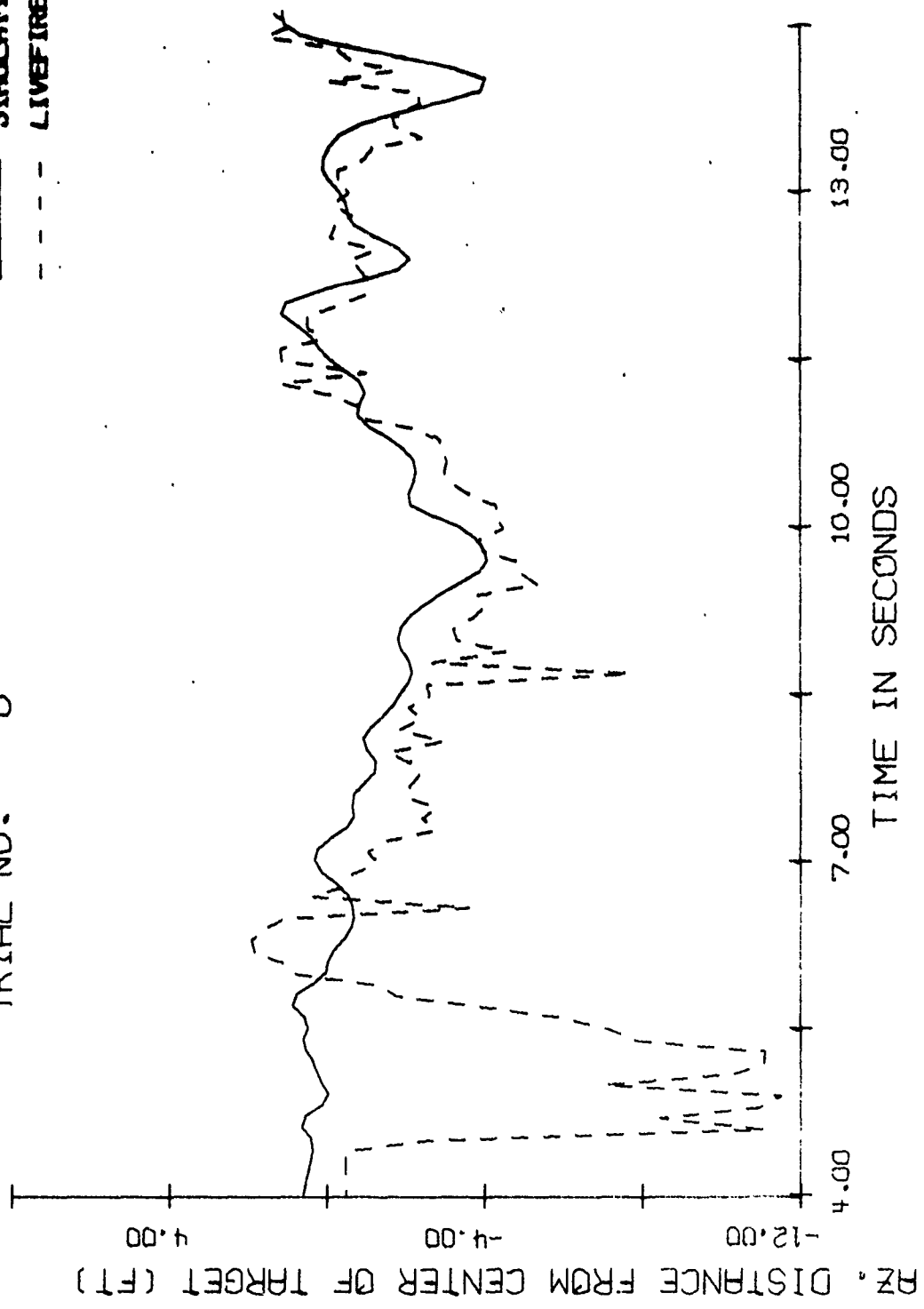
TARGET RANGE - 2855 METERS
TRIAL NO. 0

— SIMULATION
--- LIVEFIRE



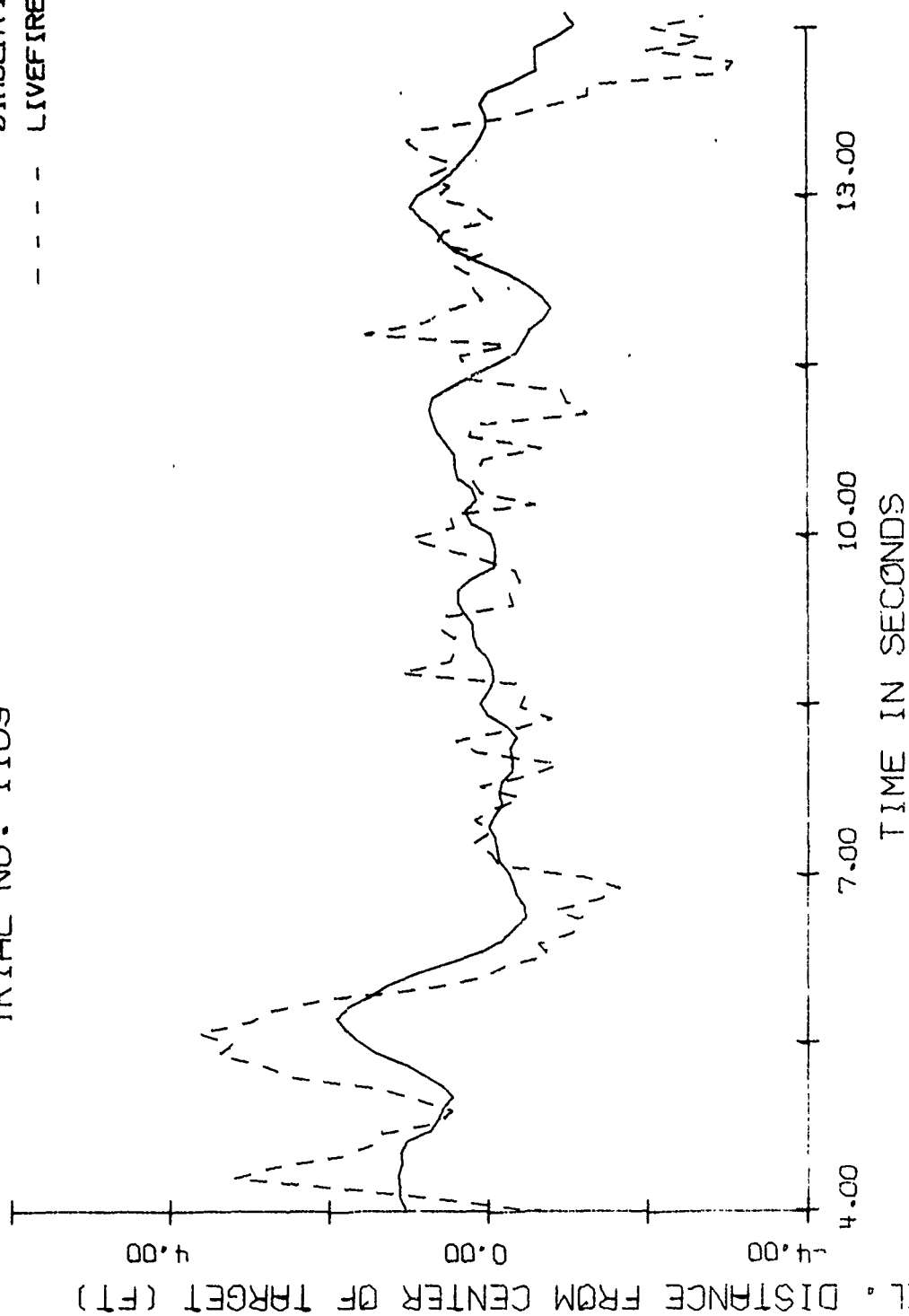
TARGET RANGE - 2855 METERS
TRIAL NO. 0

SIMULATION
LIVEFIRE



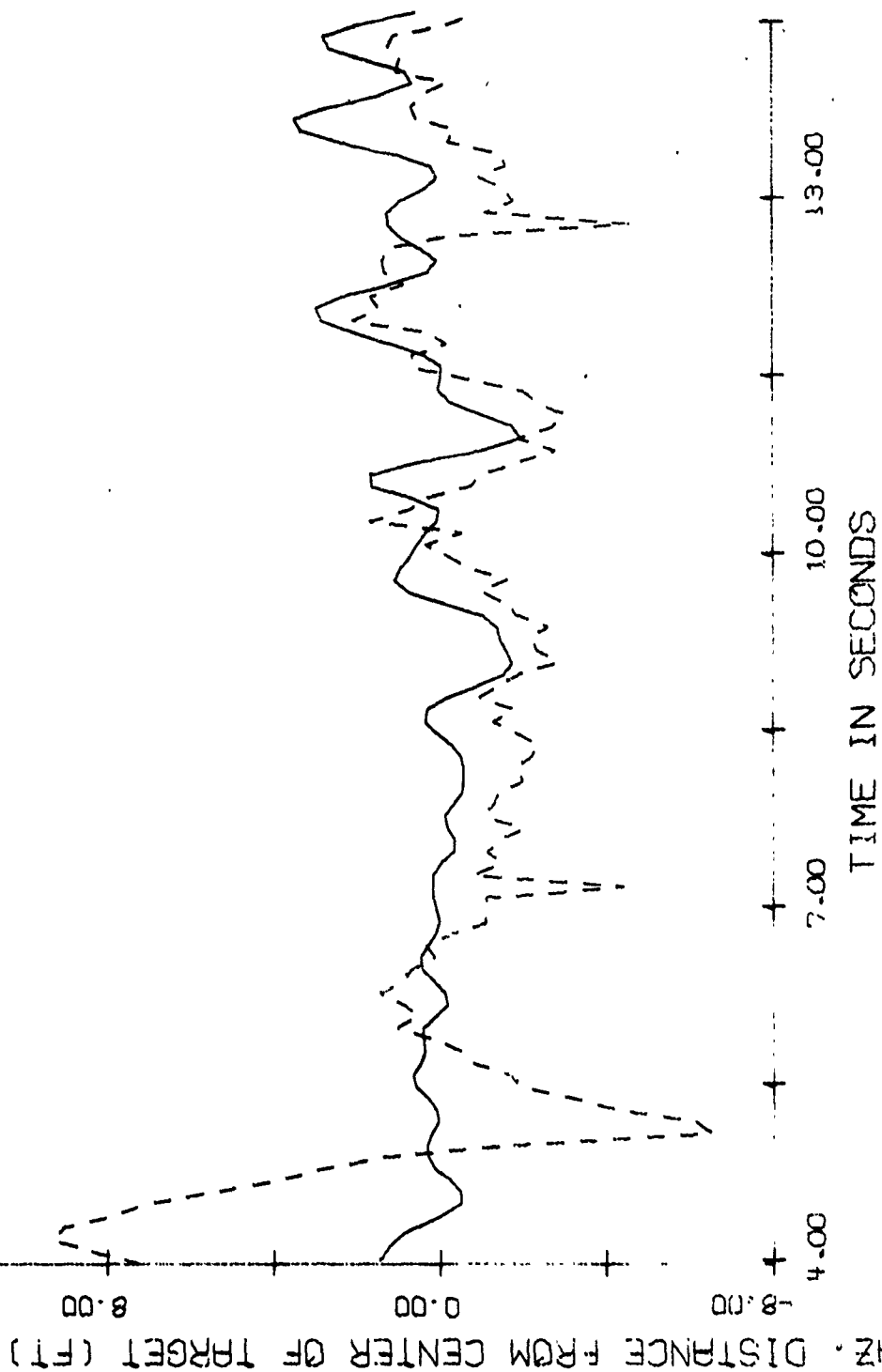
TARGET RANGE - 2855 METERS
TRIAL NO. 1109

— SIMULATION
- - - LIVEFIRE



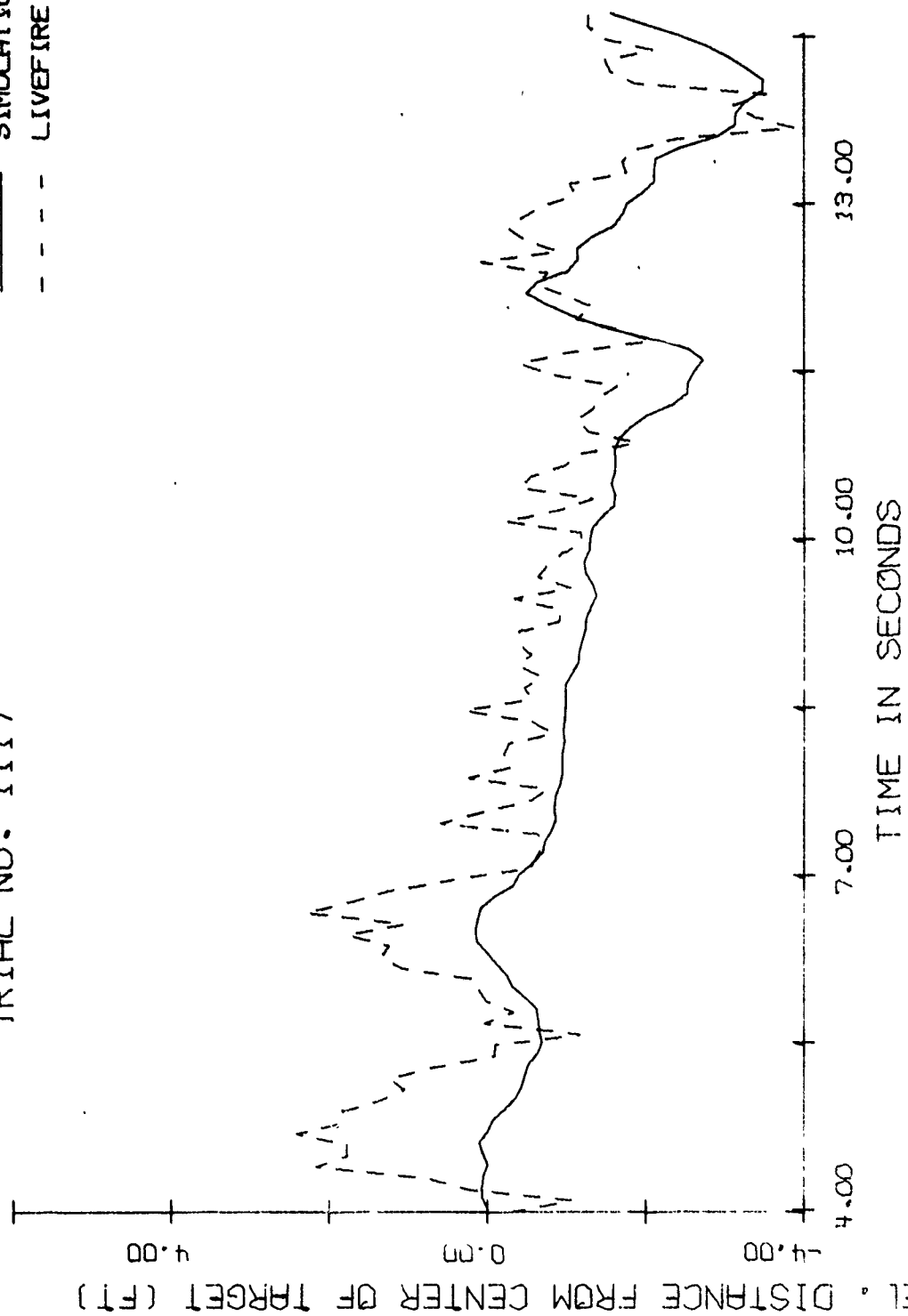
TARGET RANGE - 2855 METERS
 TRIAL NO. 1109

— SIMULATION
 - - - LIVEFIRE



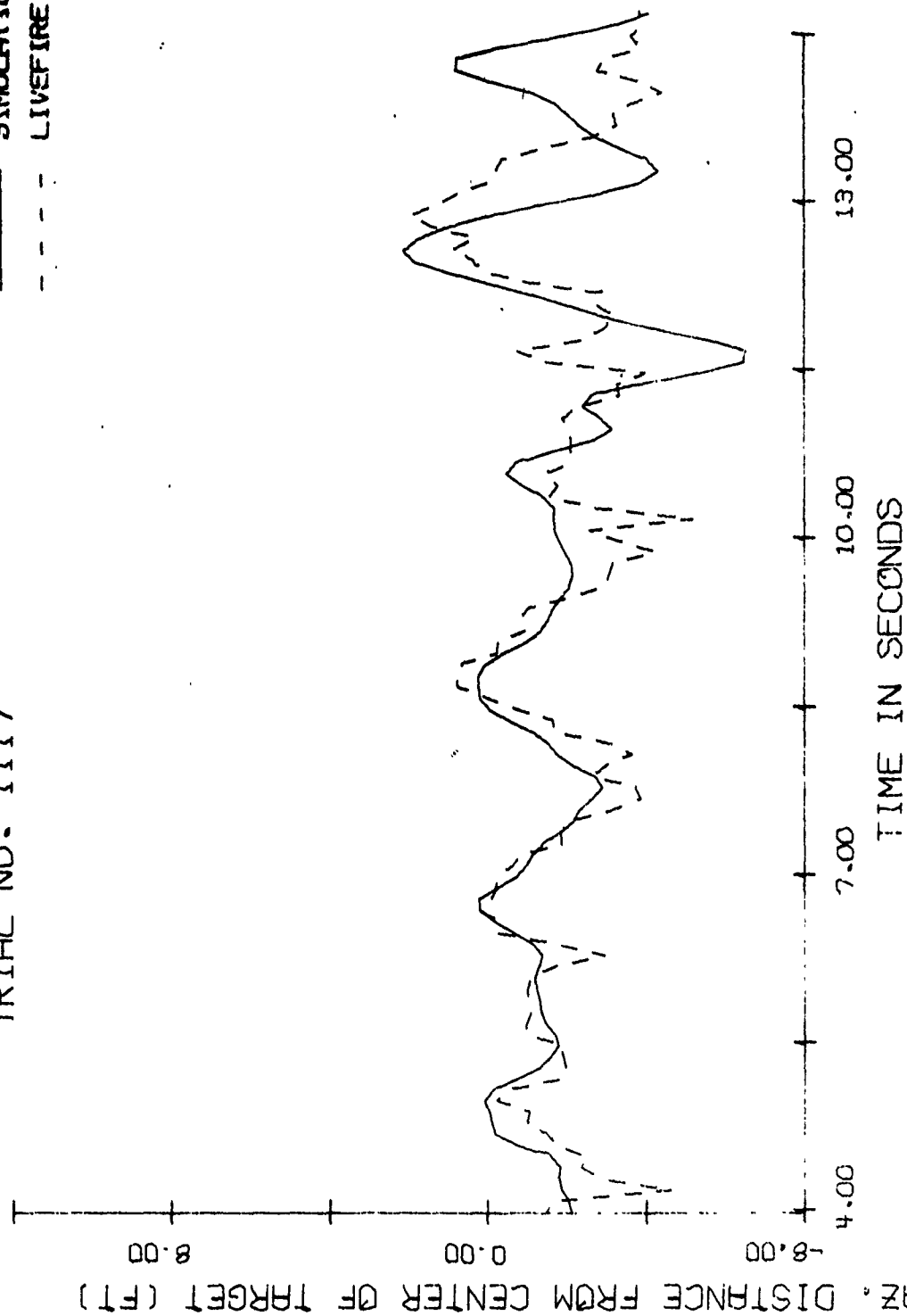
TARGET RANGE - 2855 METERS
TRIAL NO. 1117

— SIMULATION
- - - LIVEFIRE



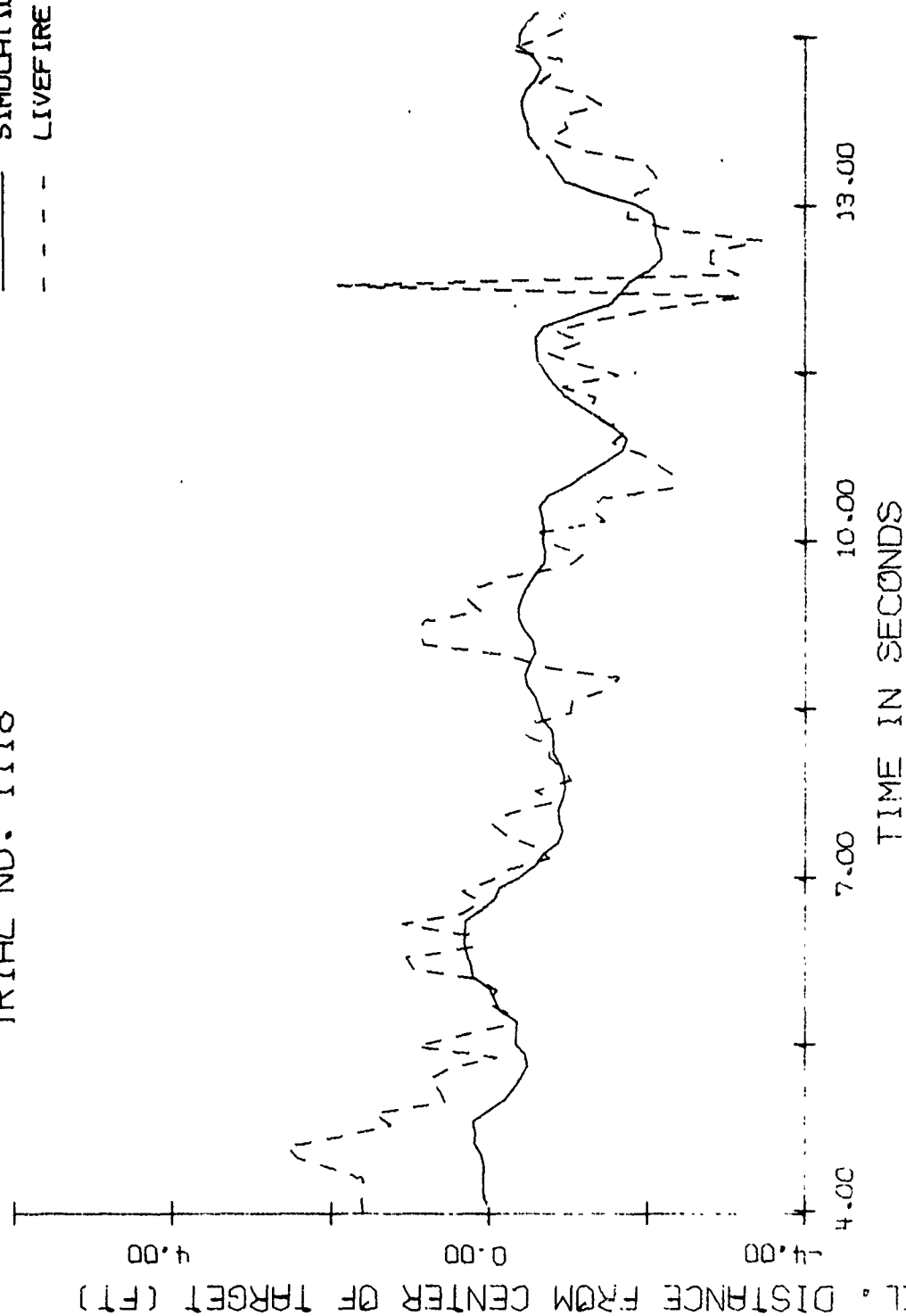
TARGET RANGE - 2855 METERS
TRIAL NO. 1117

— SIMULATION
- - - LIVEFIRE



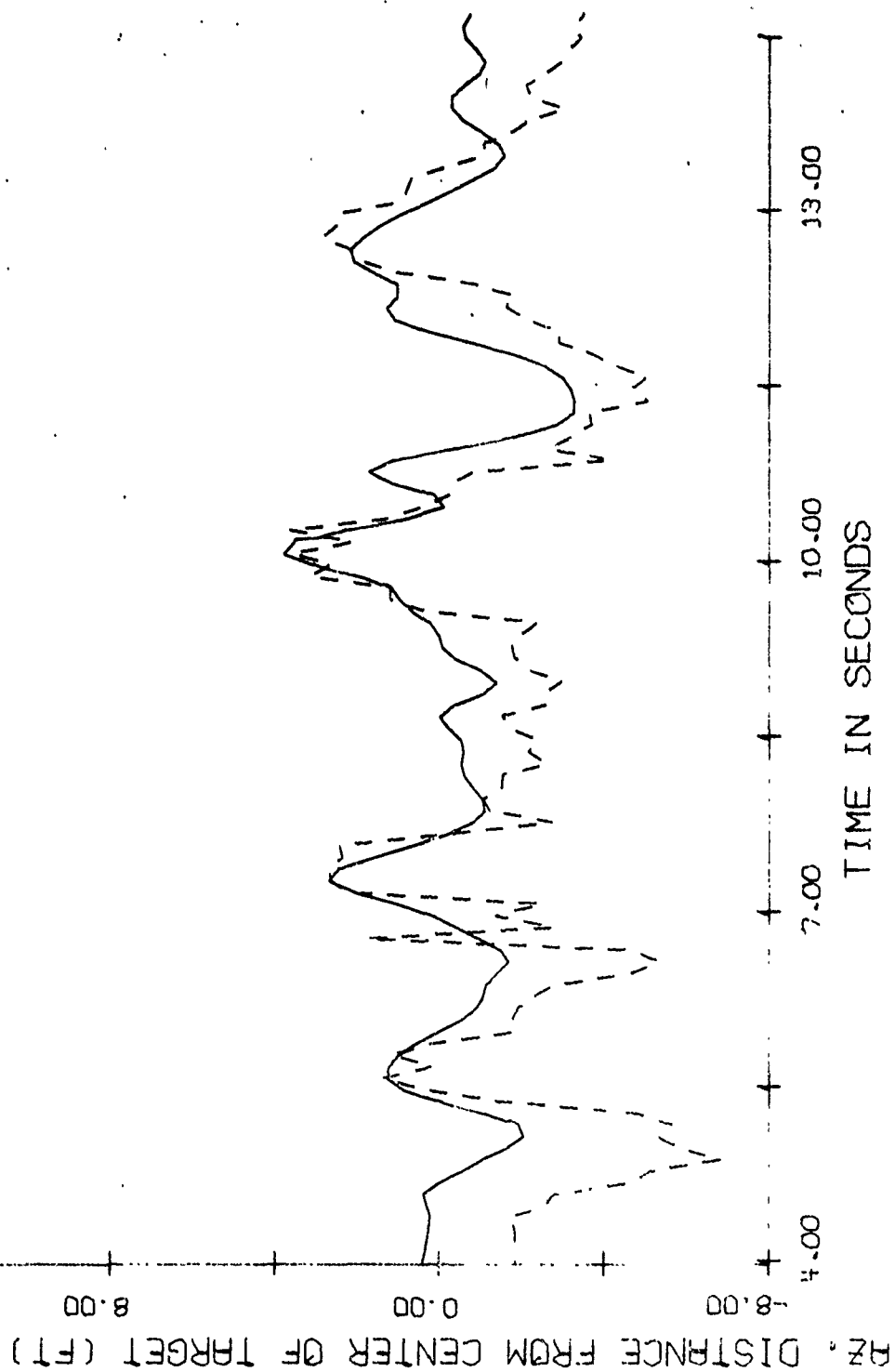
TARGET RANGE - 2855 METERS
TRIAL NO. 1118

— SIMULATION
- - - LIVEFIRE



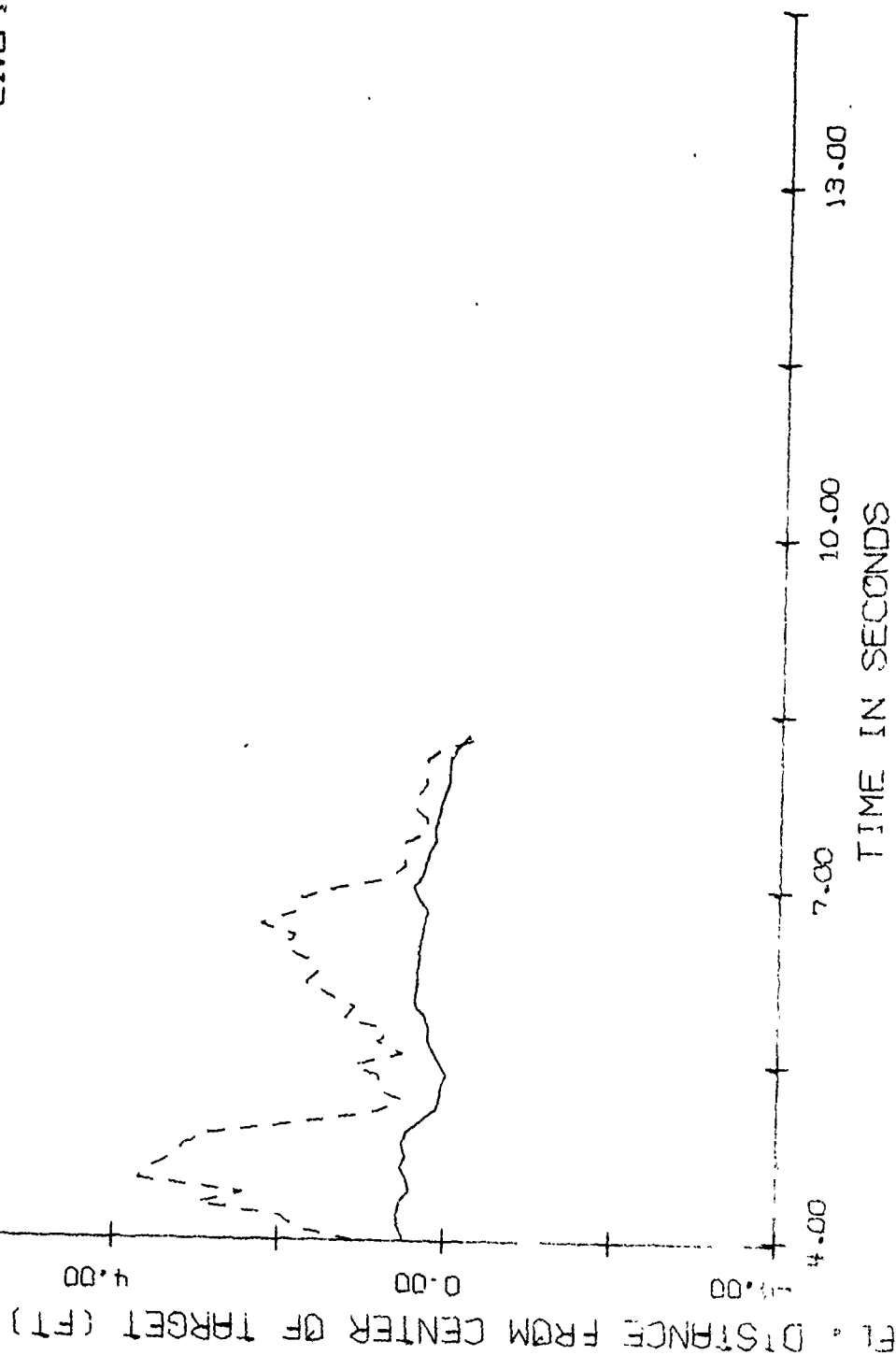
TARGET RANGE - 2855 METERS
TRIAL NO. 1118

— SIMULATION
- - - LIVEFIRE



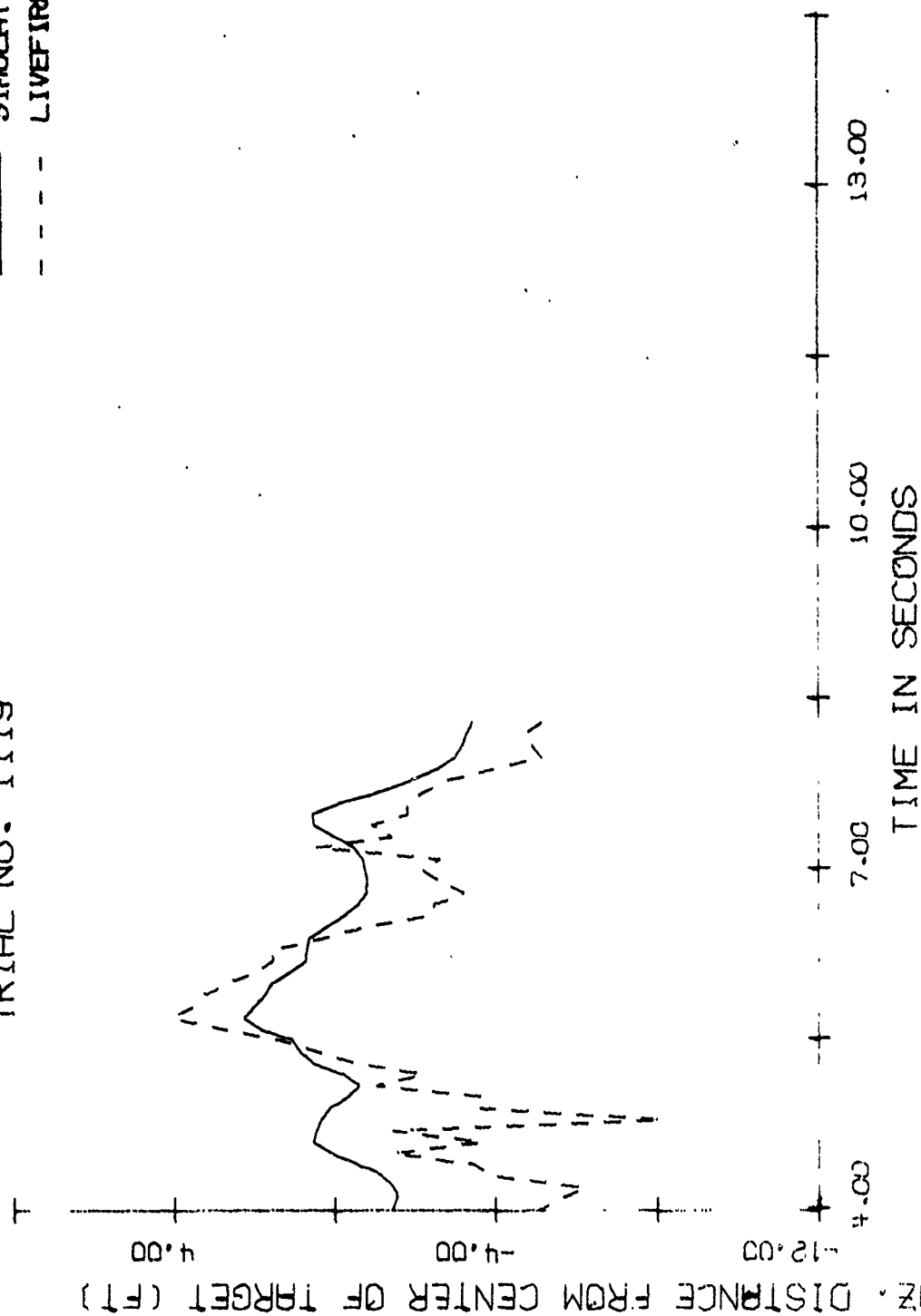
TARGET RANGE - 2855 METERS
TRIAL NO. 1119

— SIMULATION
- - - LIVEFIRE



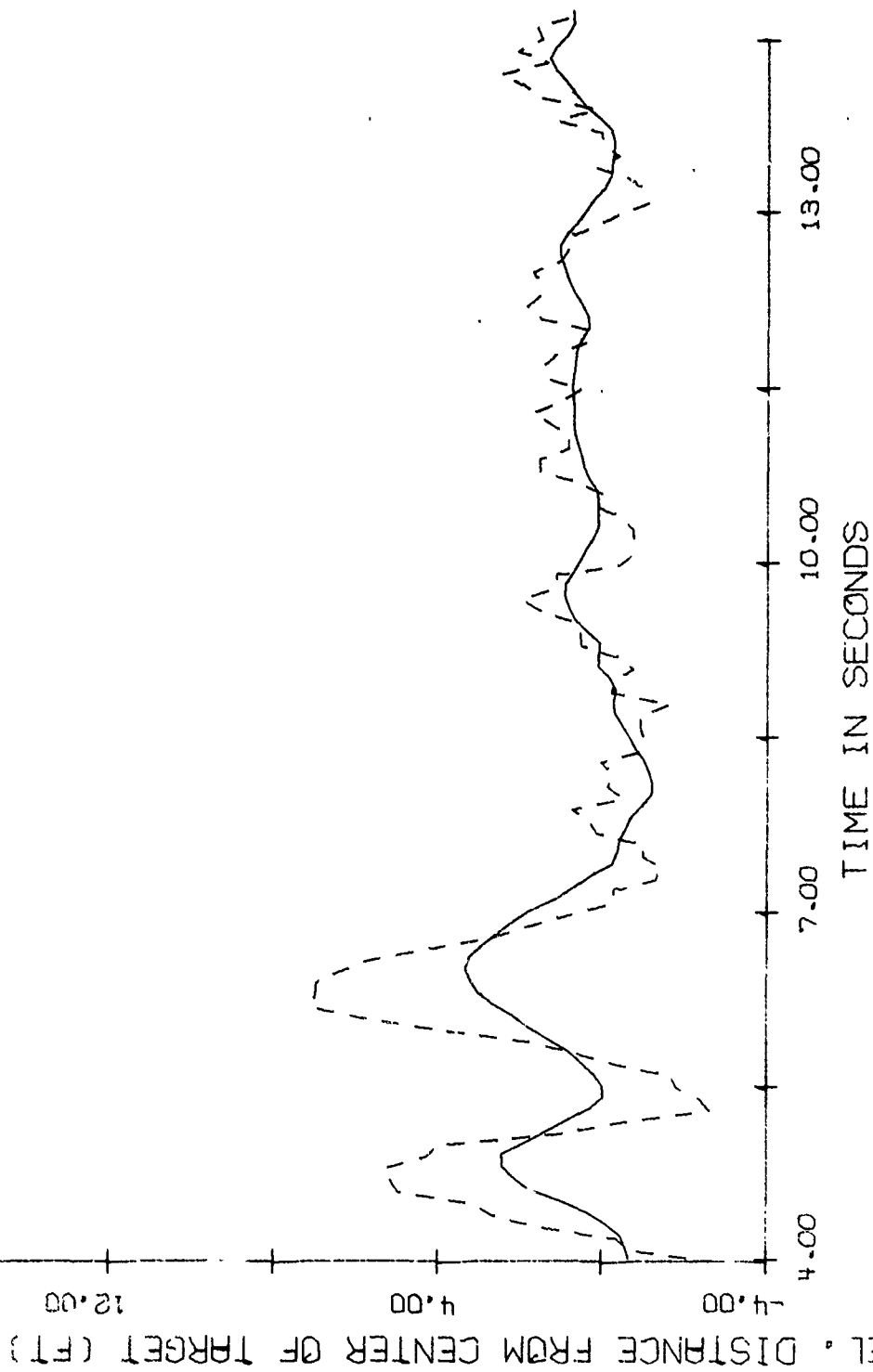
TARGET RANGE - 2855 METERS
 TRIAL NO. 1119

— SIMULATION
 --- LIVEFIRE

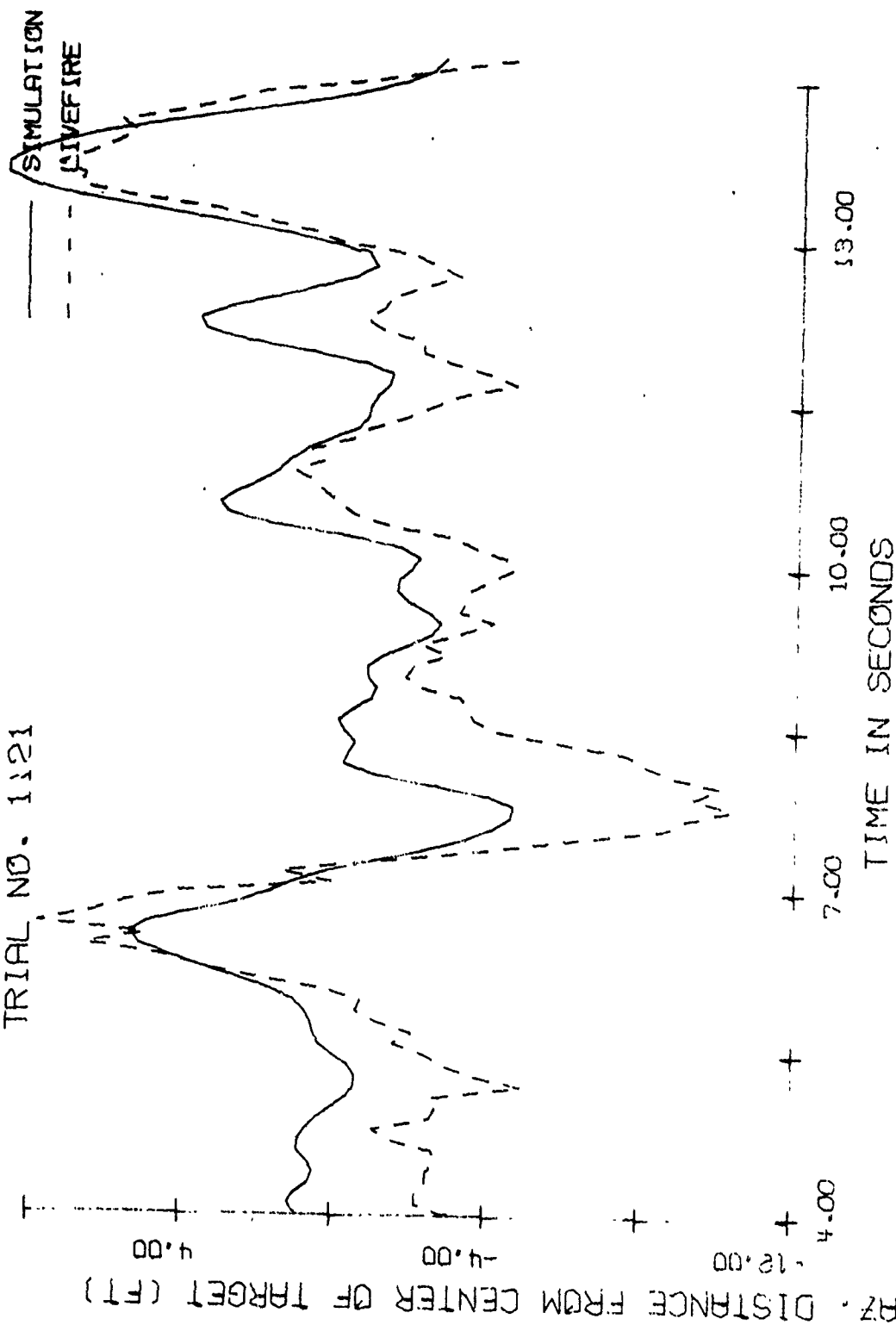


TARGET RANGE - 2855 METERS
TRIAL NO. 1121

— SIMULATION
- - - LIVEFIRE



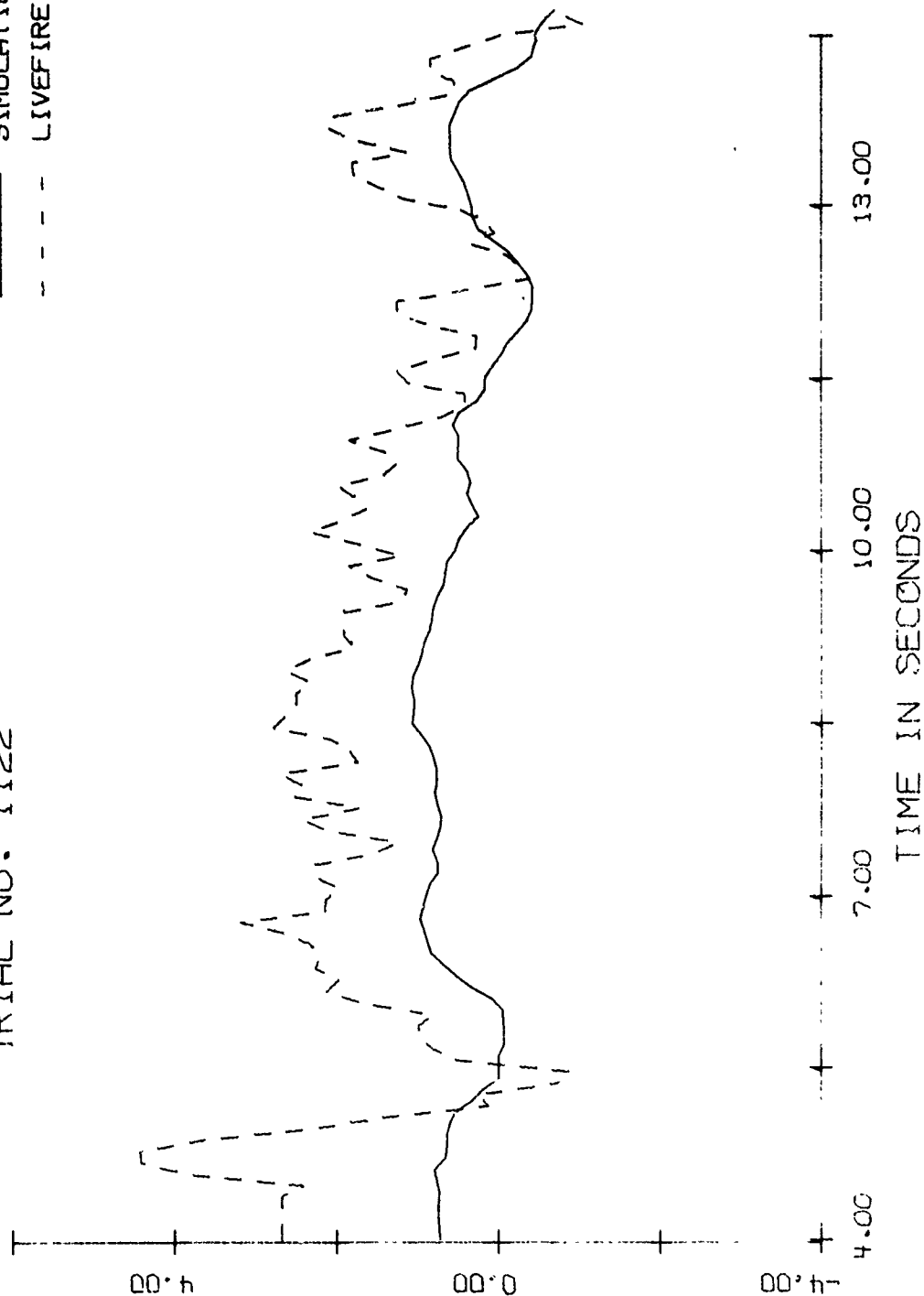
TARGET RANGE - 2855 METERS
 TRIAL NO. 1121



TARGET RANGE - 2855 METERS
 TRIAL NO. 1122

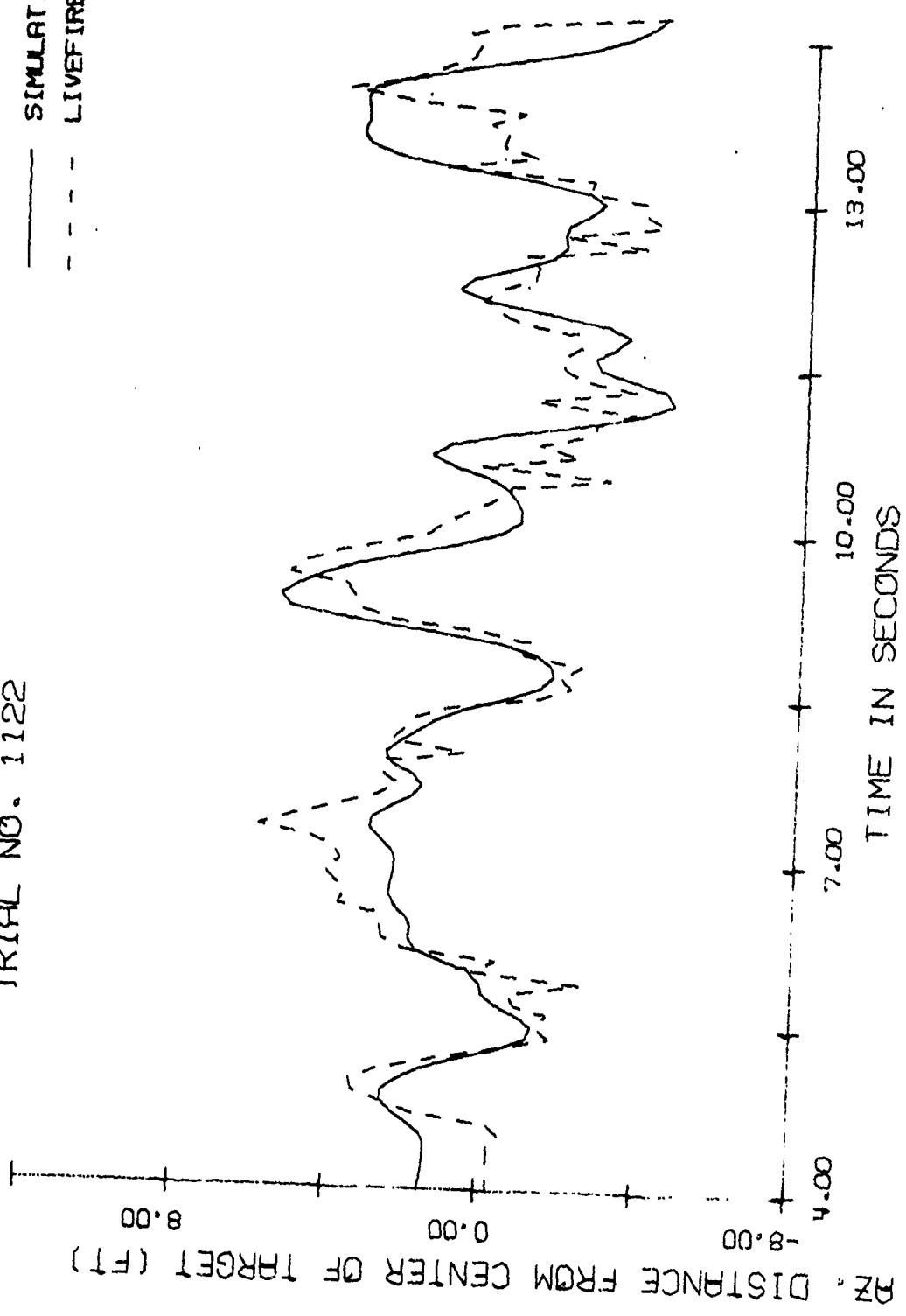
— SIMULATION
 - - - LIVEFIRE

FL. DISTANCE FROM CENTER OF TARGET (FT)



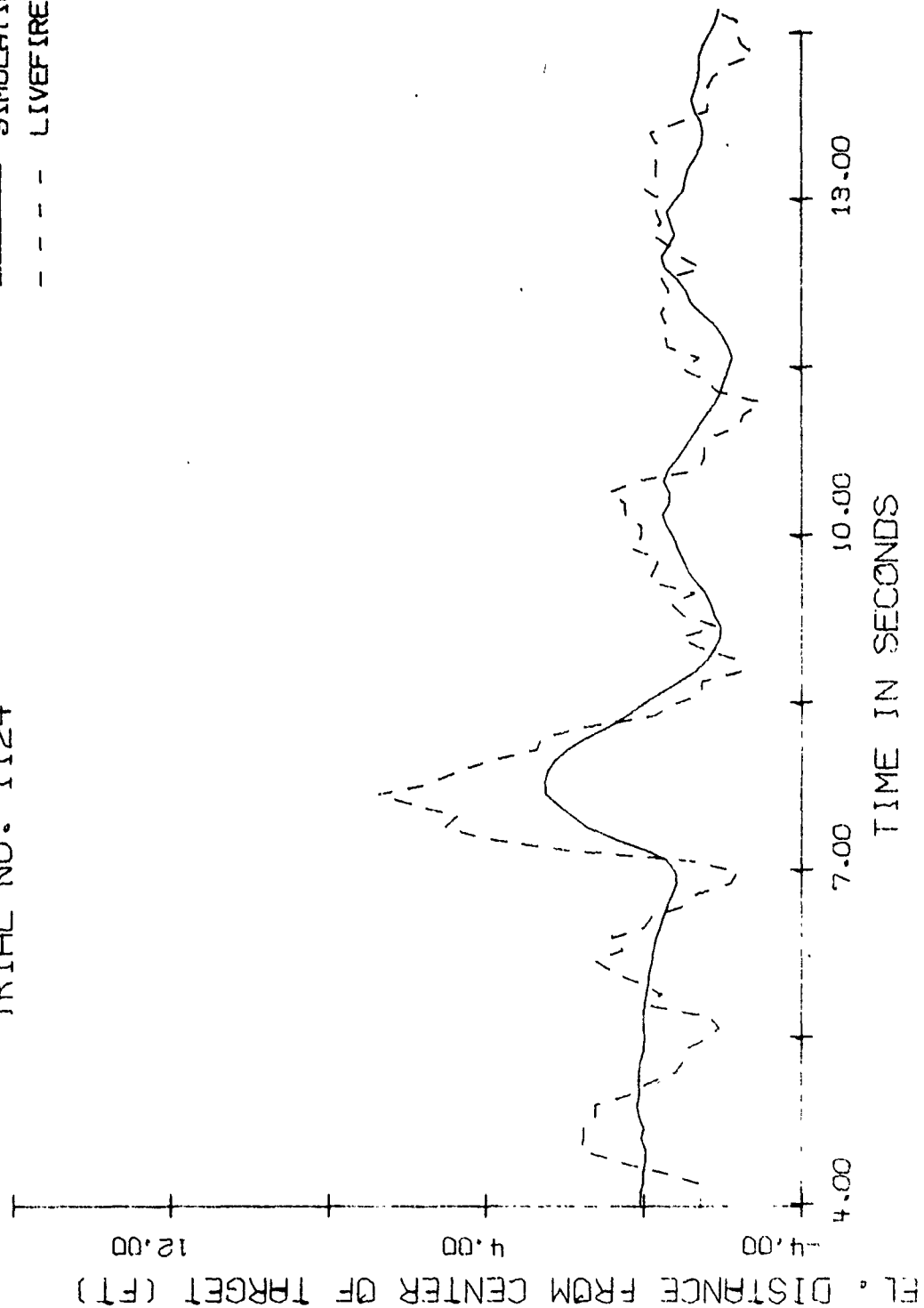
TARGET RANGE - 2855 METERS
 TRIAL NO. 1122

— SIMULATION
 --- LIVEFIRE



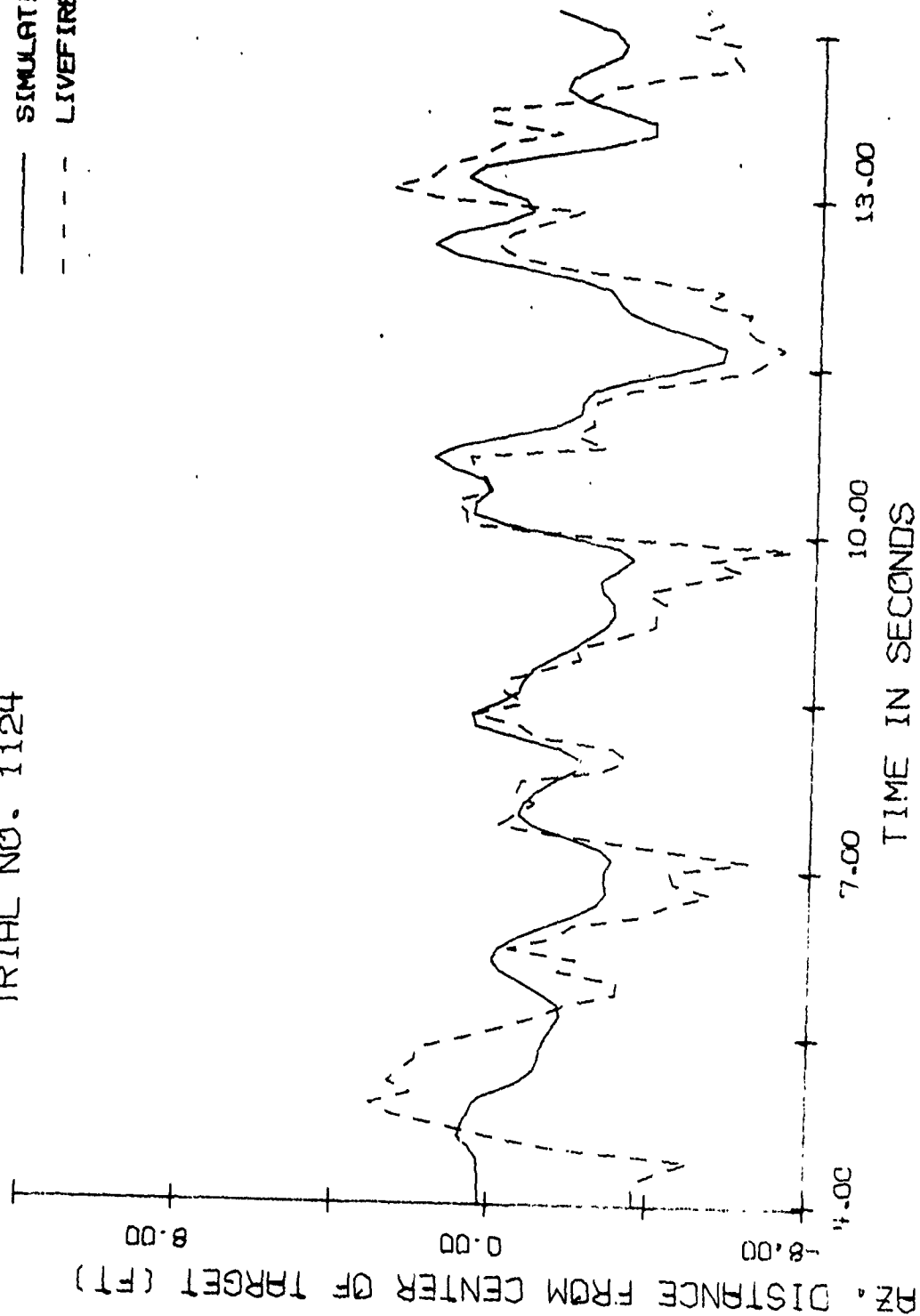
TARGET RANGE - 2855 METERS
TRIAL NO. 1124

— SIMULATION
- - - LIVEFIRE



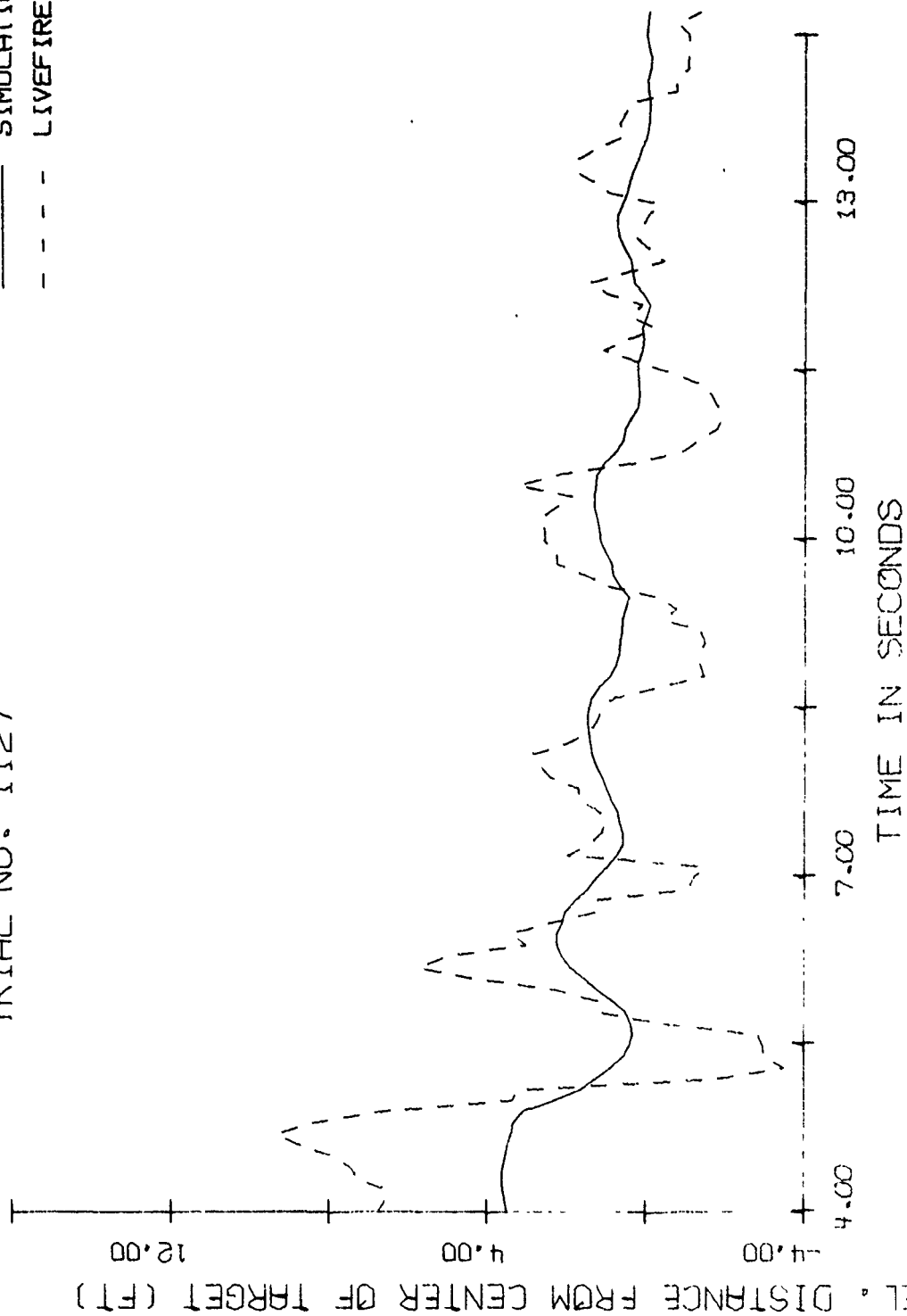
TARGET RANGE - 2855 METERS
TRIAL NO. 1124

— SIMULATION
- - - LIVEFIRE



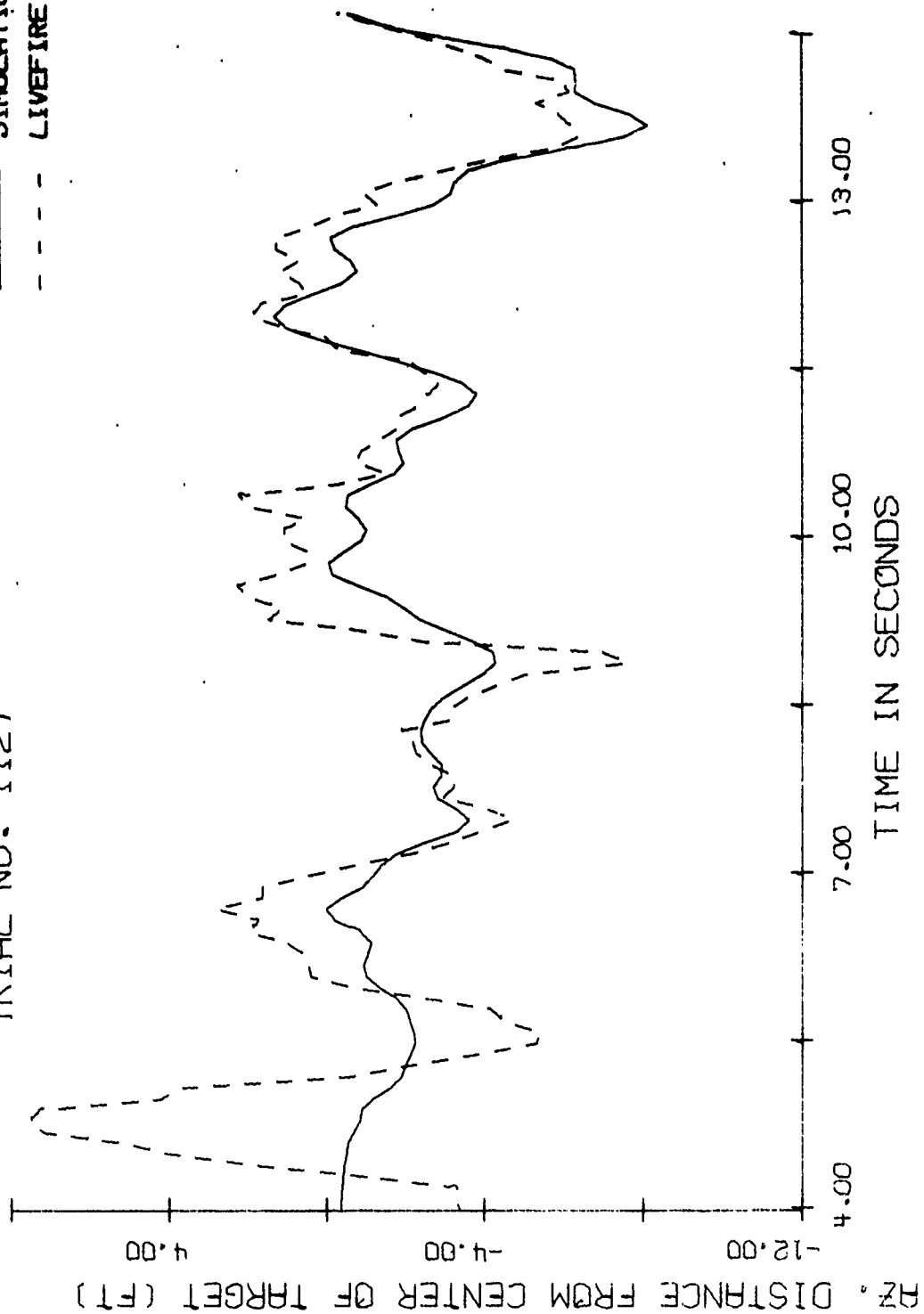
TARGET RANGE - 2855 METERS
 TRIAL NO. 1127

— SIMULATION
 - - - LIVEFIRE



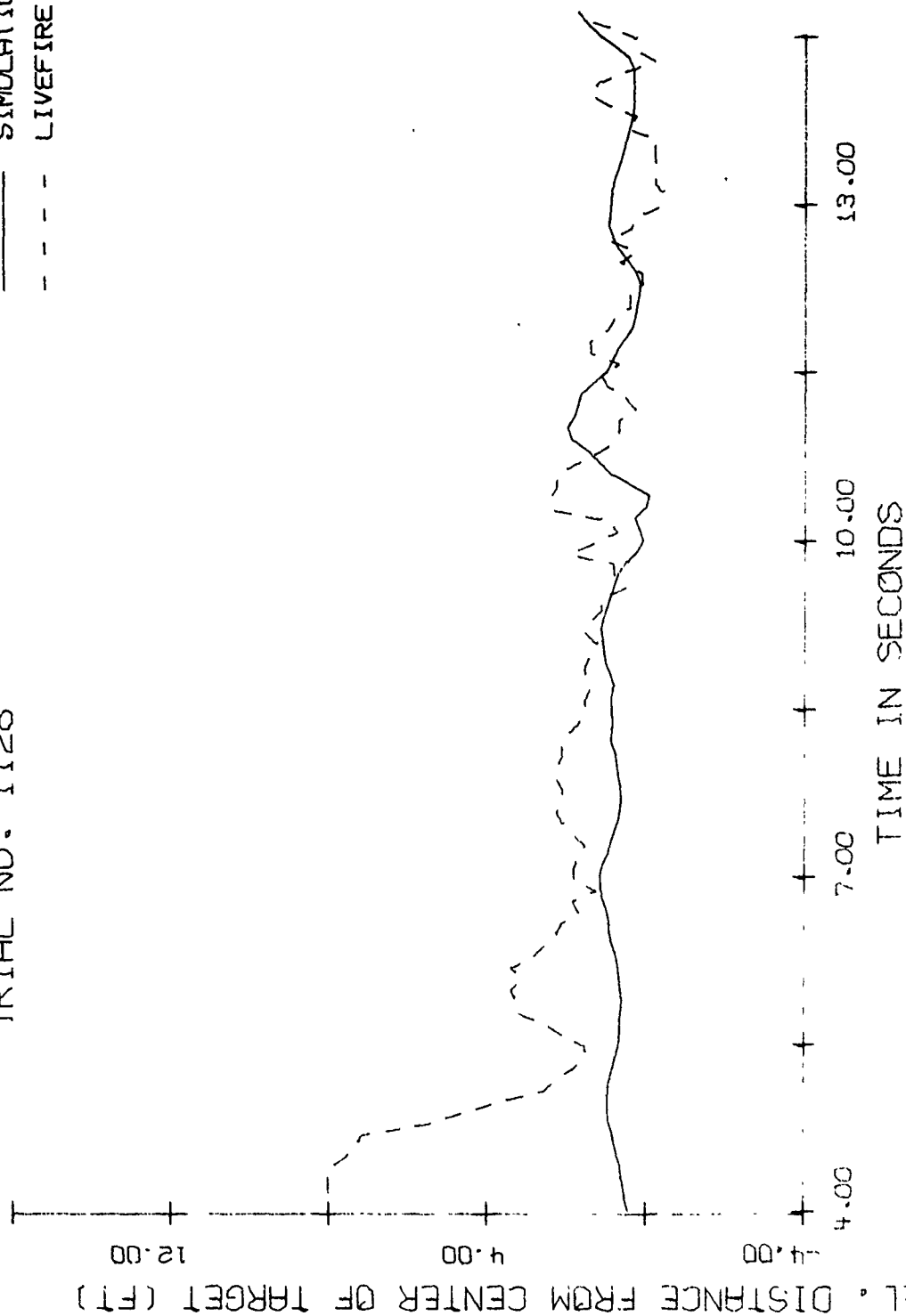
TARGET RANGE - 2855 METERS
TRIAL NO. 1127

— SIMULATION
--- LIVEFIRE



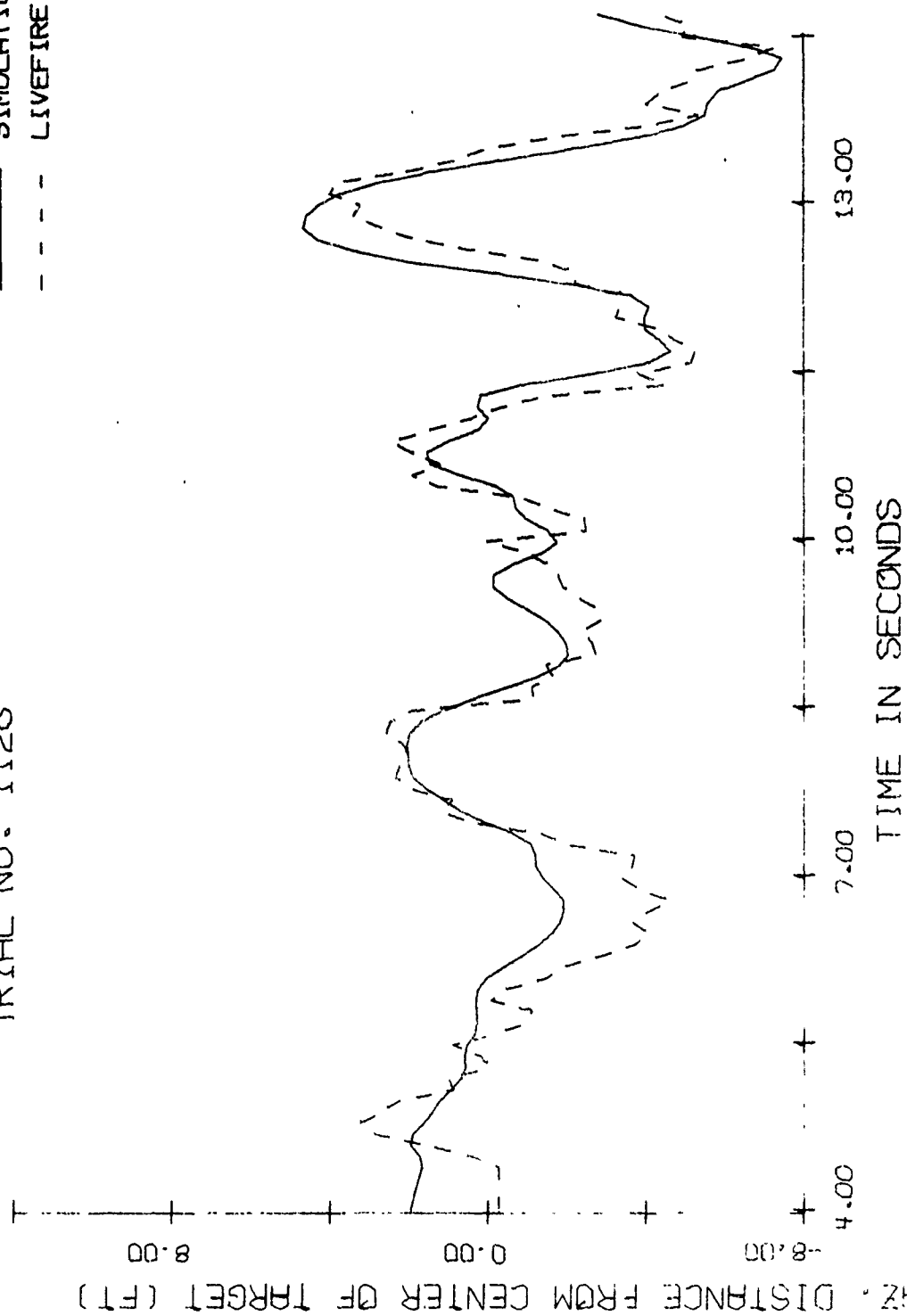
TARGET RANGE - 2855 METERS
 TRIAL NO. 1128

— SIMULATION
 - - - LIVEFIRE



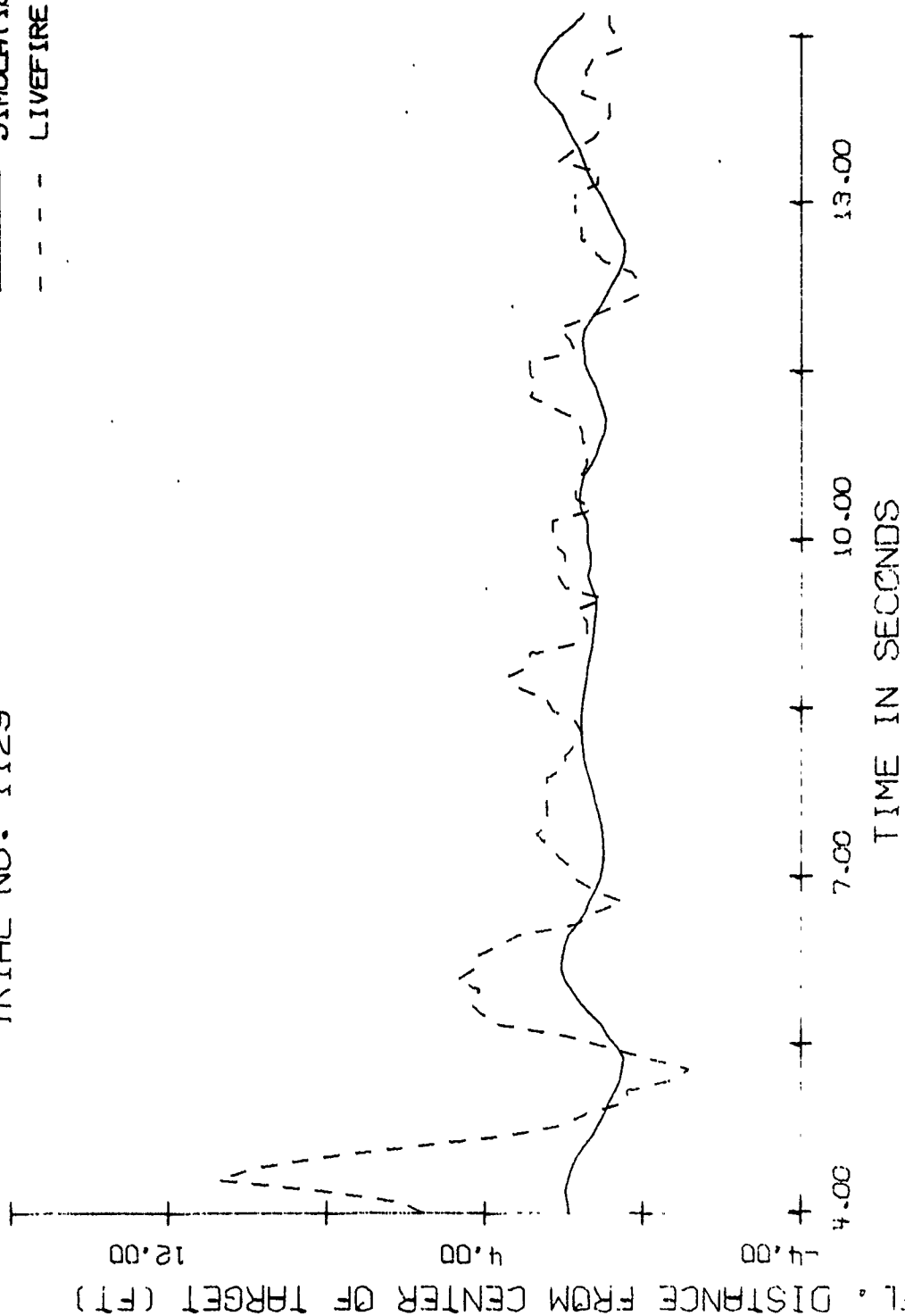
TARGET RANGE - 2855 METERS
 TRIAL NO. 1128

— SIMULATION
 - - - LIVEFIRE



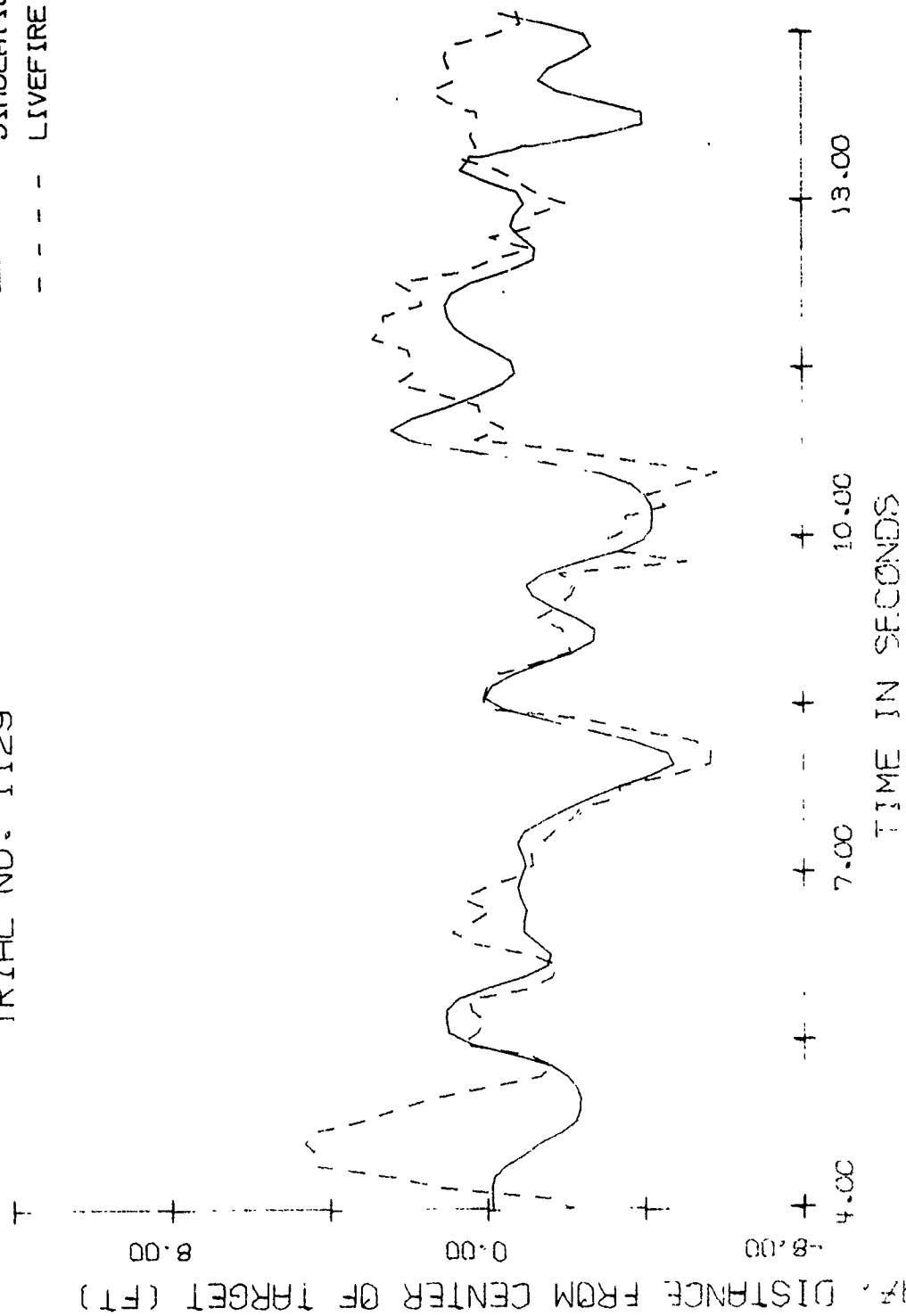
TARGET RANGE - 2855 METERS
 TRIAL NO. 1129

— SIMULATION
 - - - LIVEFIRE



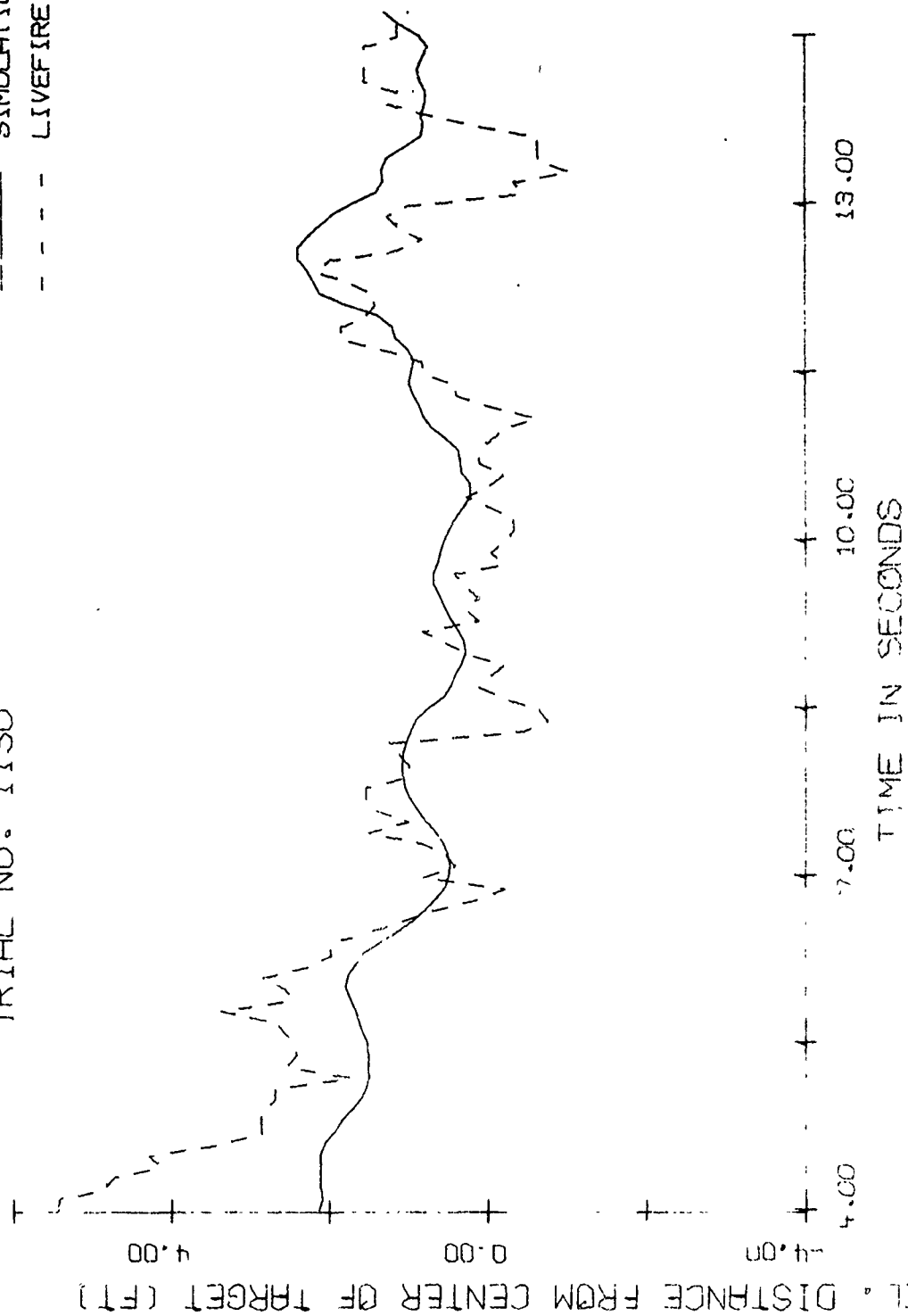
TARGET RANGE - 2855 METERS
 TRIAL NO. 1129

— SIMULATION
 - - - LIVEFIRE



TARGET RANGE - 2855 METERS
 TRIAL NO. 1130

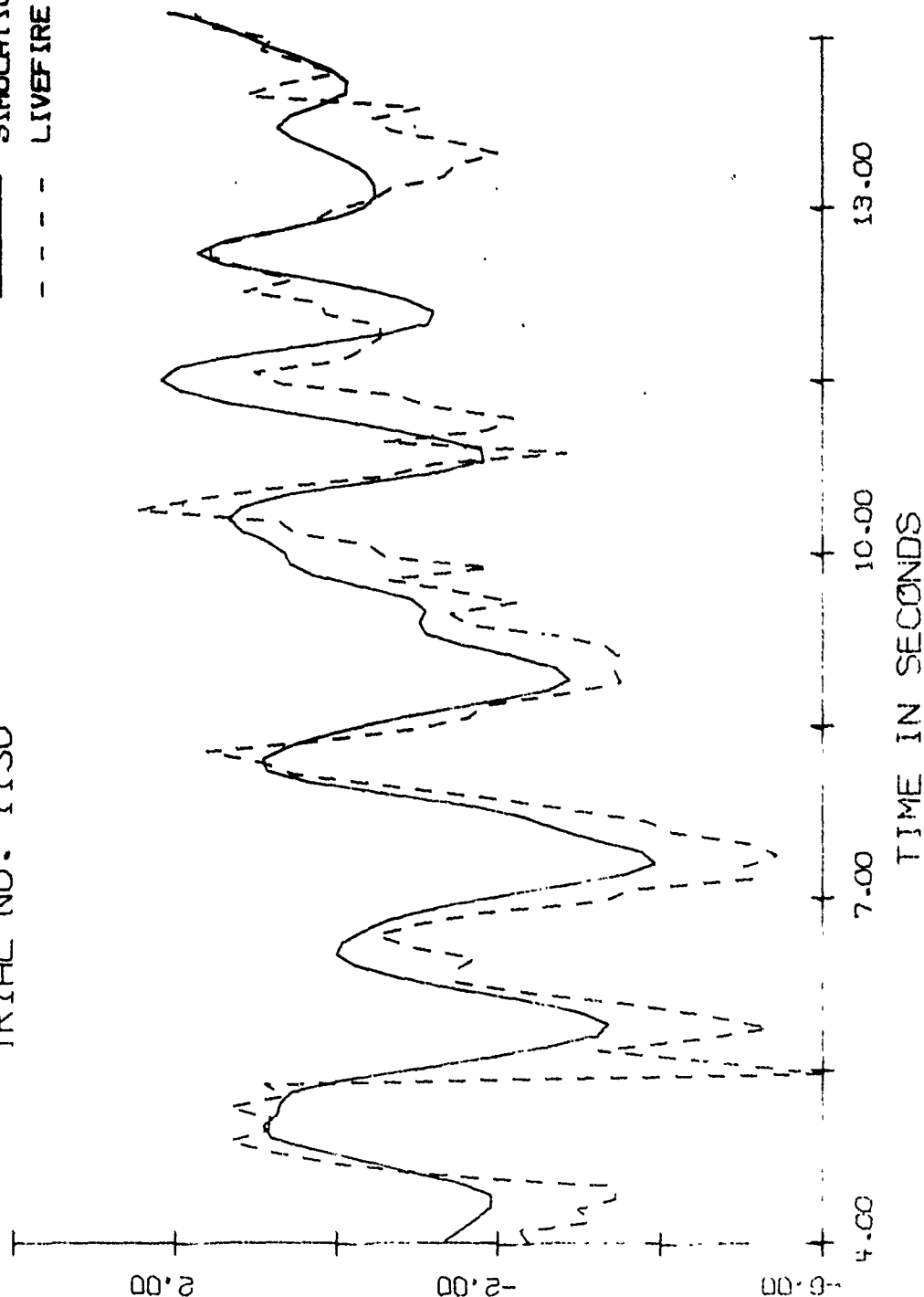
— SIMULATION
 - - - LIVEFIRE



AZ. DISTANCE FROM CENTER OF TARGET (FT)

— SIMULATION
- - - LIVEFIRE

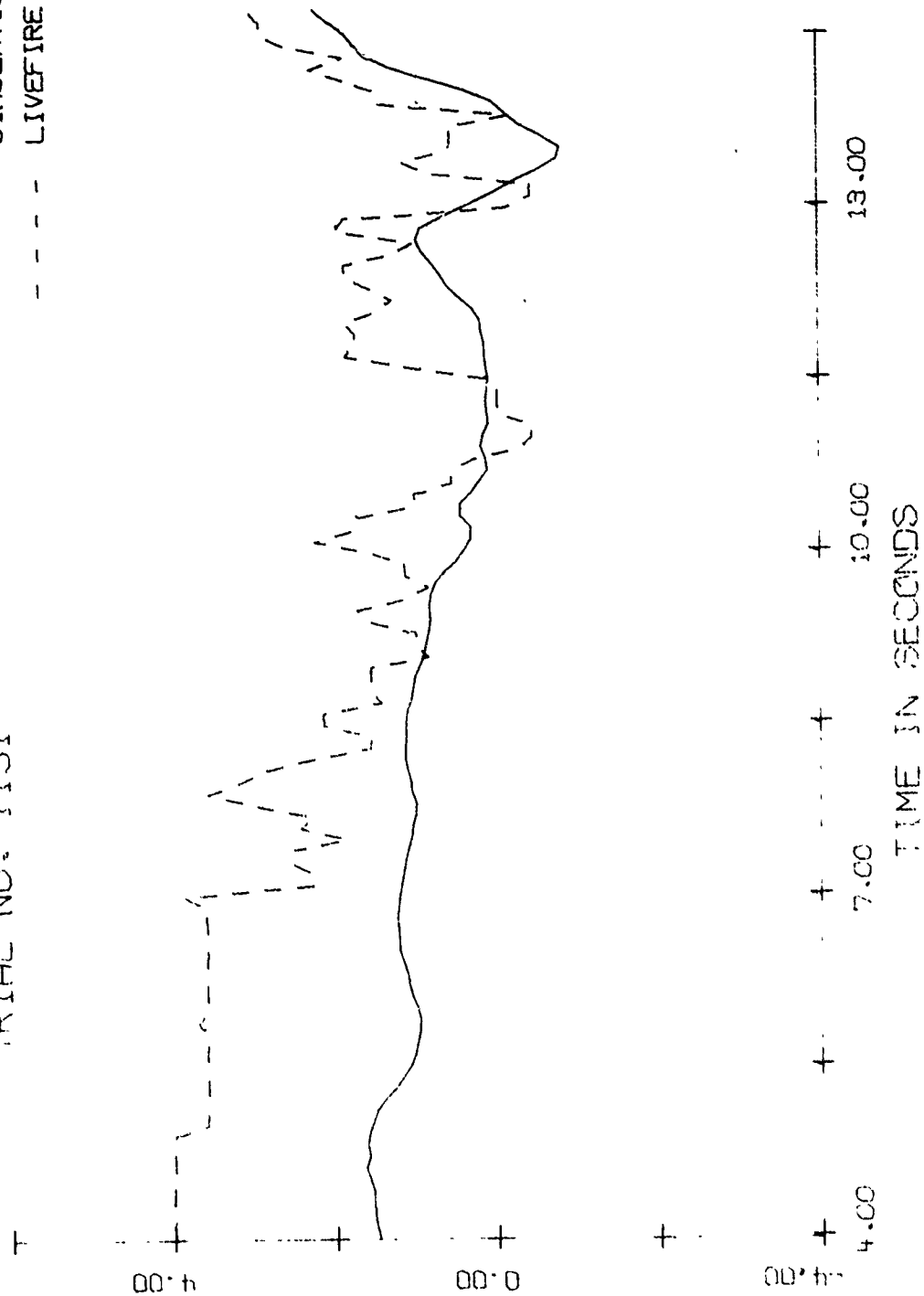
TARGET RANGE - 2855 METERS
TRIAL NO. 1130



TARGET RANGE - 2353 METERS
 TRIAL NO. 1131

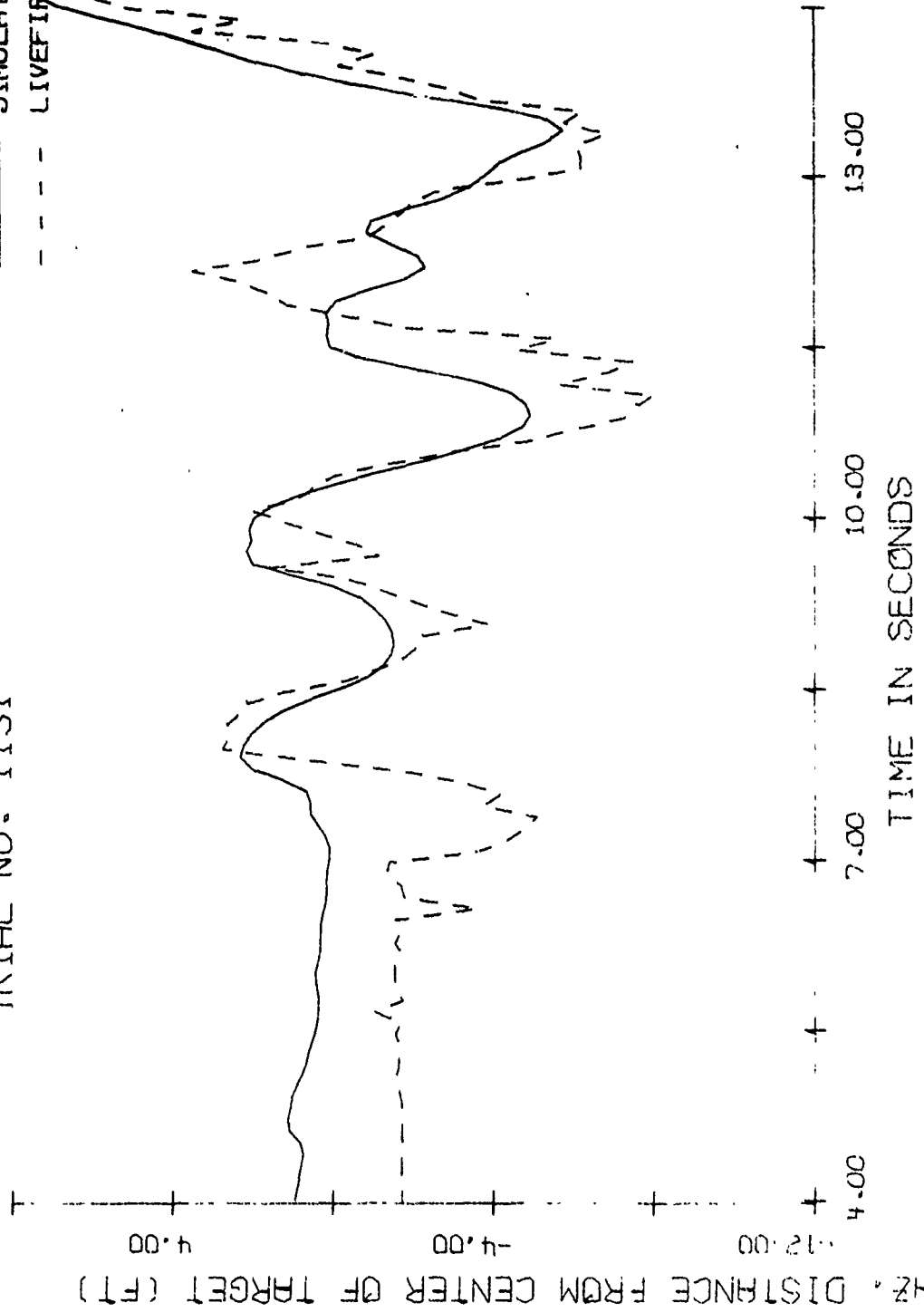
— SIMULATION
 - - - LIVEFIRE

FL. DISTANCE FROM CENTER OF TARGET (FT)



TARGET RANGE - 2855 METERS
TRIAL NO. 1131

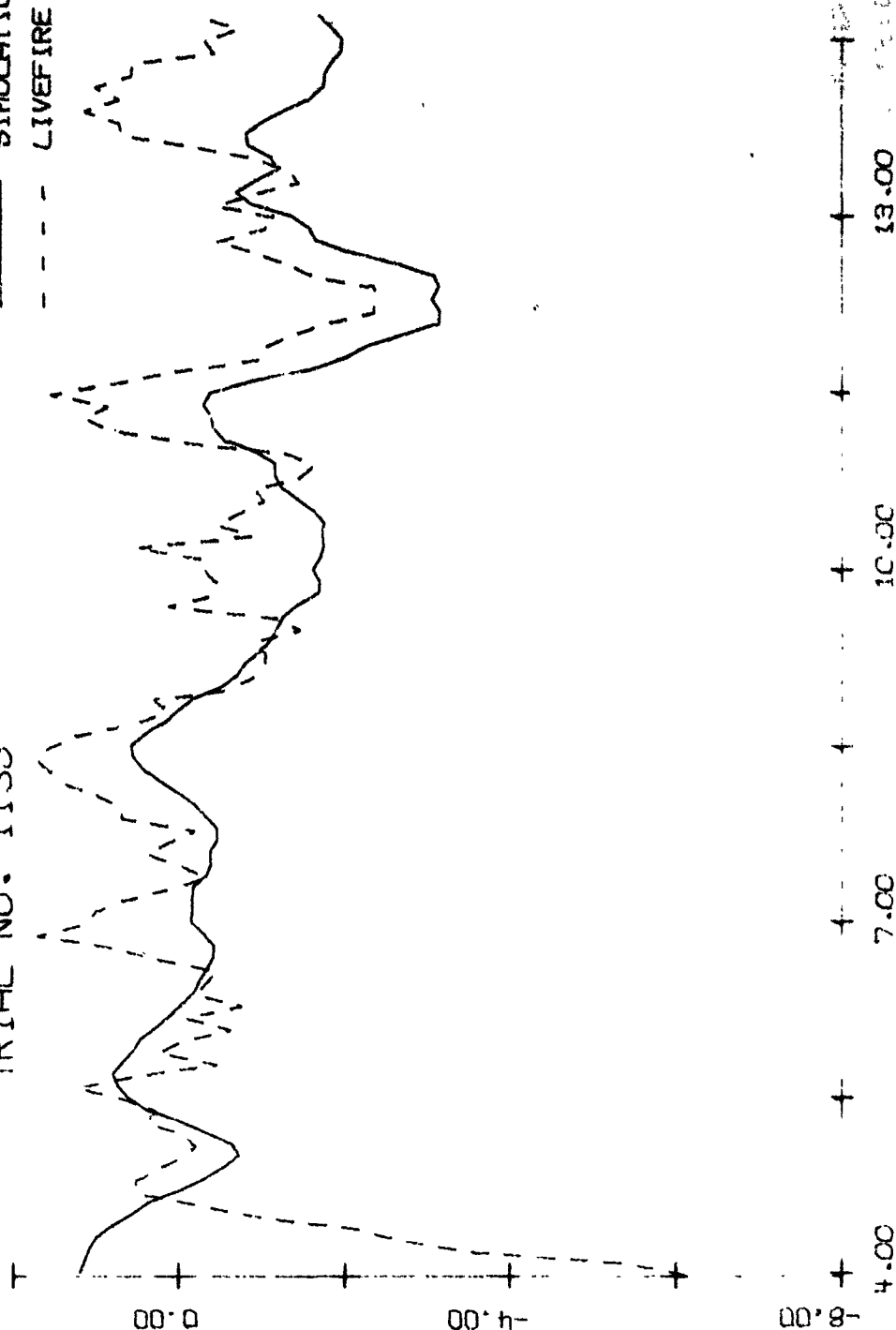
— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1135

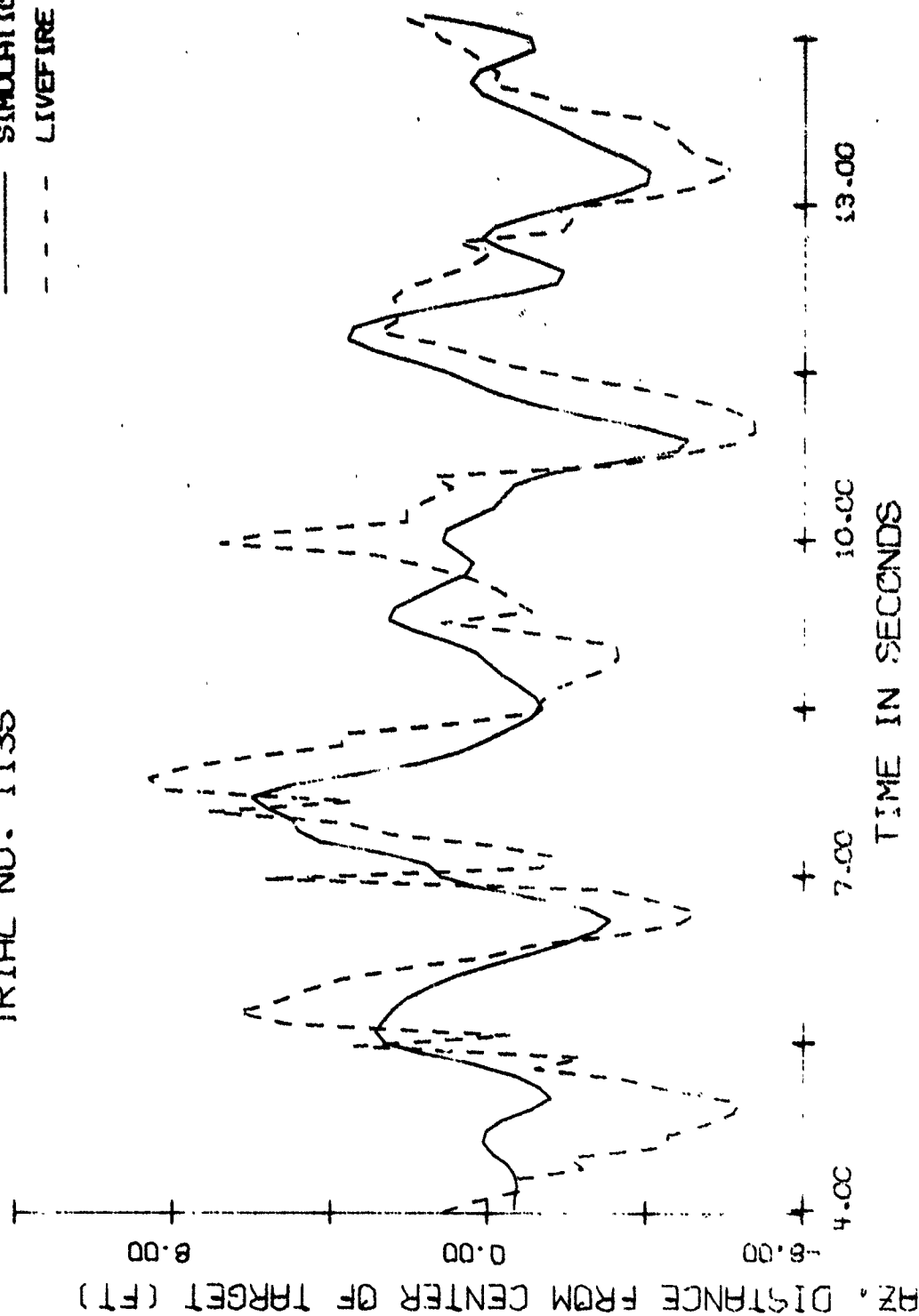
— SIMULATION
- - - LIVEFIRE

FL. DISTANCE FROM CENTER OF TARGET (FT)



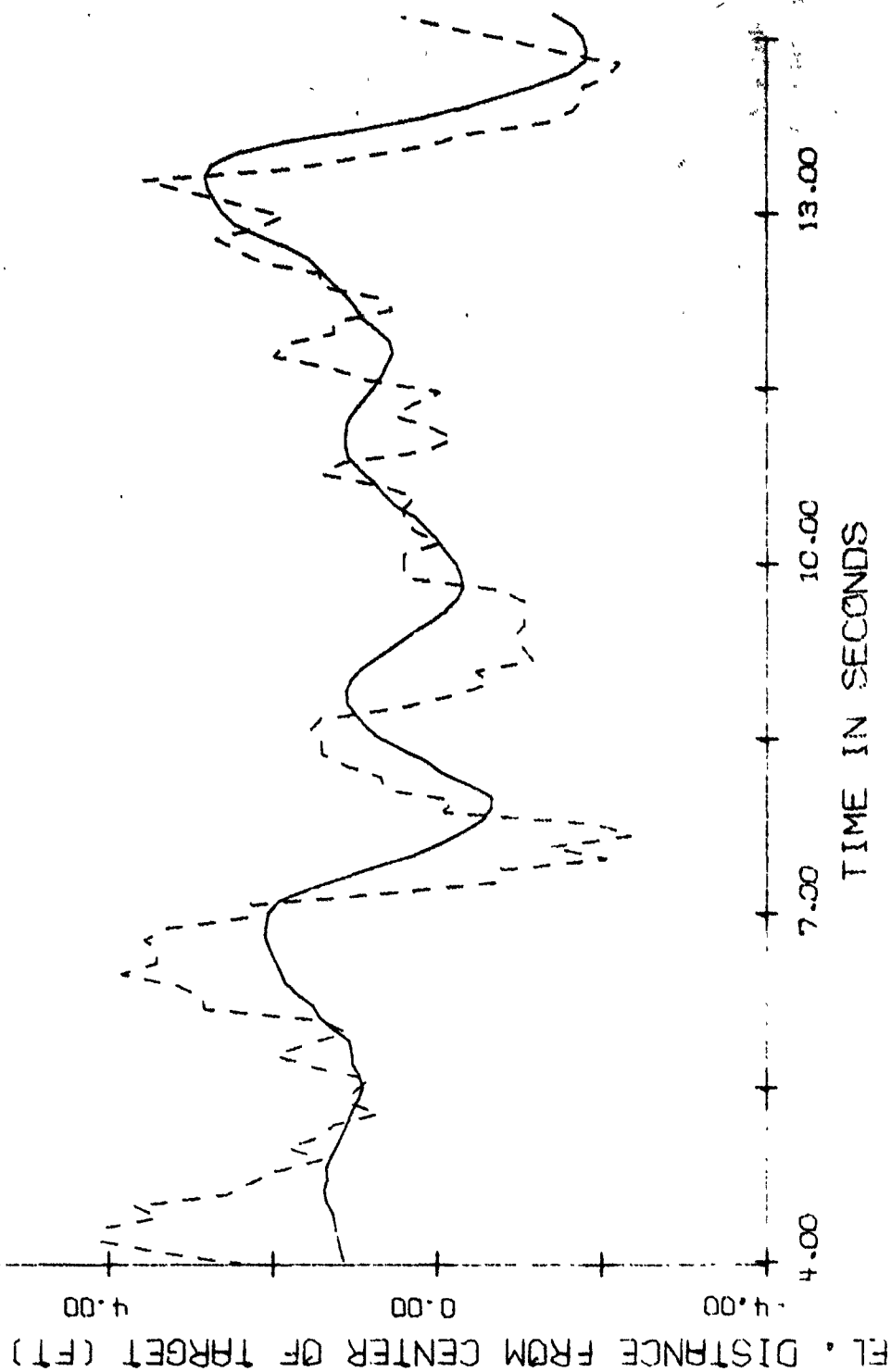
TARGET RANGE - 2855 METERS
TRIAL NO. 1135

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1136

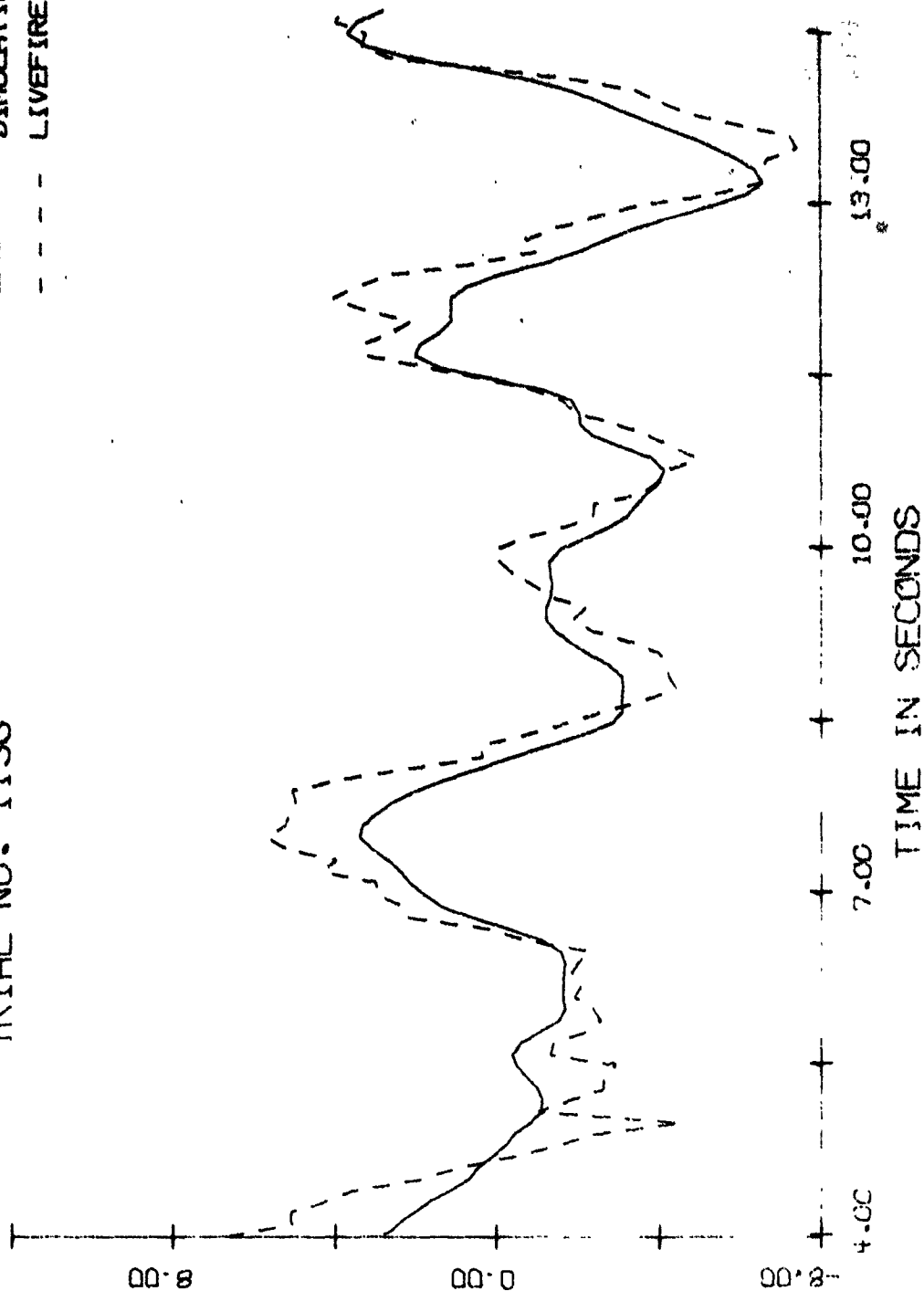
— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1136

— SIMULATION
- - - LIVEFIRE

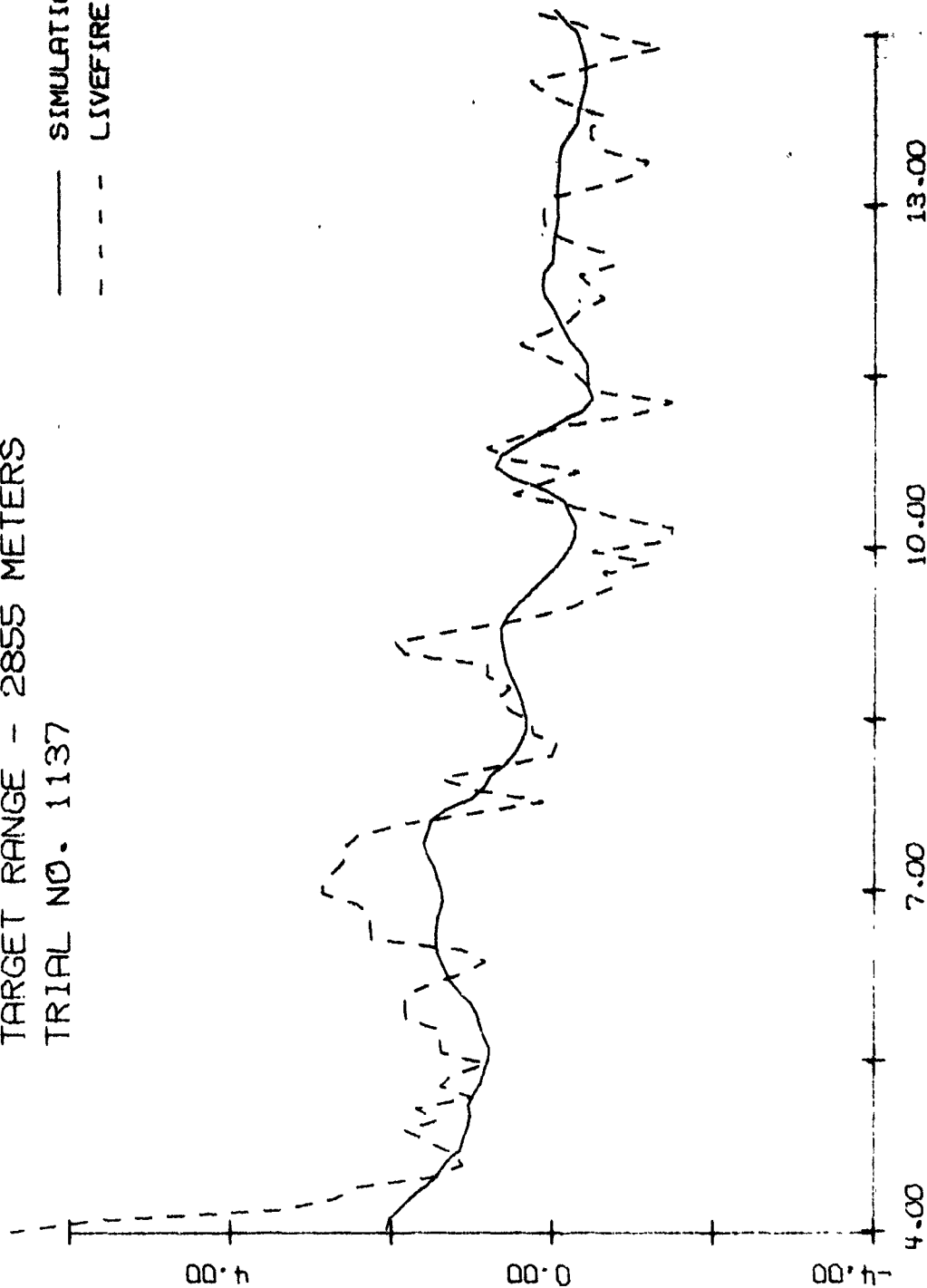
AZ. DISTANCE FROM CENTER OF TARGET (FT)



TARGET RANGE - 2855 METERS
TRIAL NO. 1137

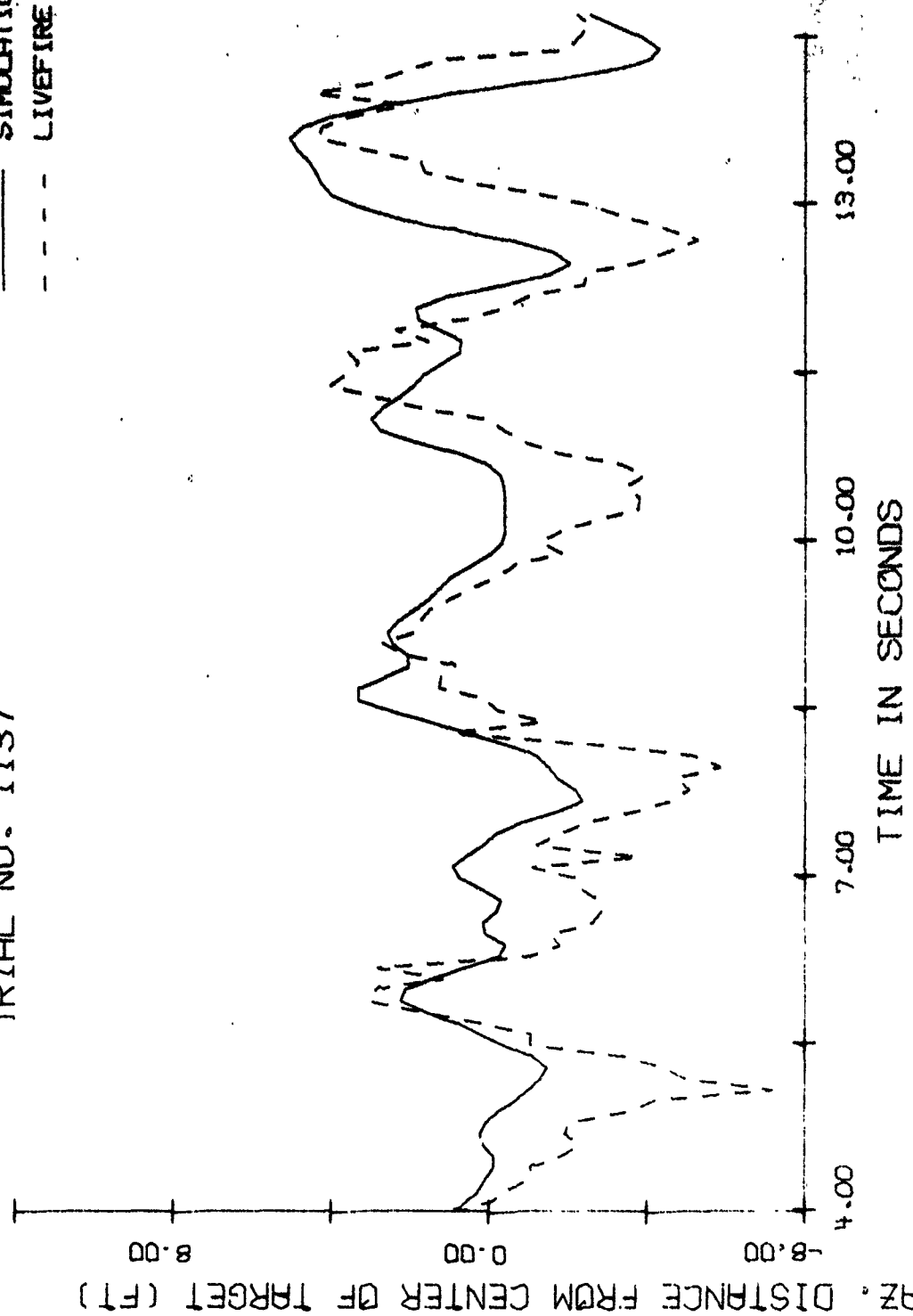
— SIMULATION
- - - LIVEFIRE

EL. DISTANCE FROM CENTER OF TARGET (FT)



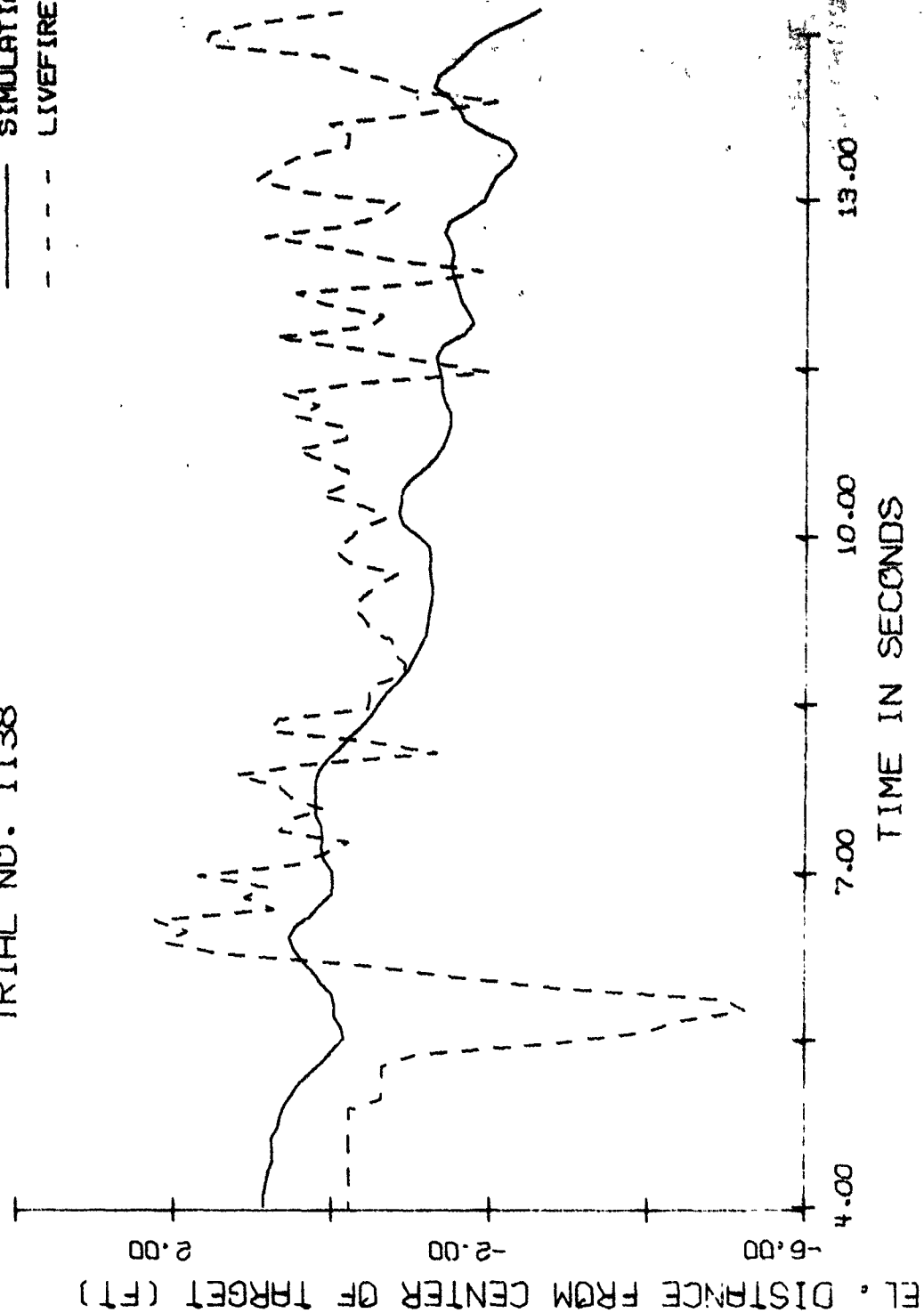
TARGET RANGE - 2855 METERS
TRIAL NO. 1137

— SIMULATION
- - - LIVEFIRE



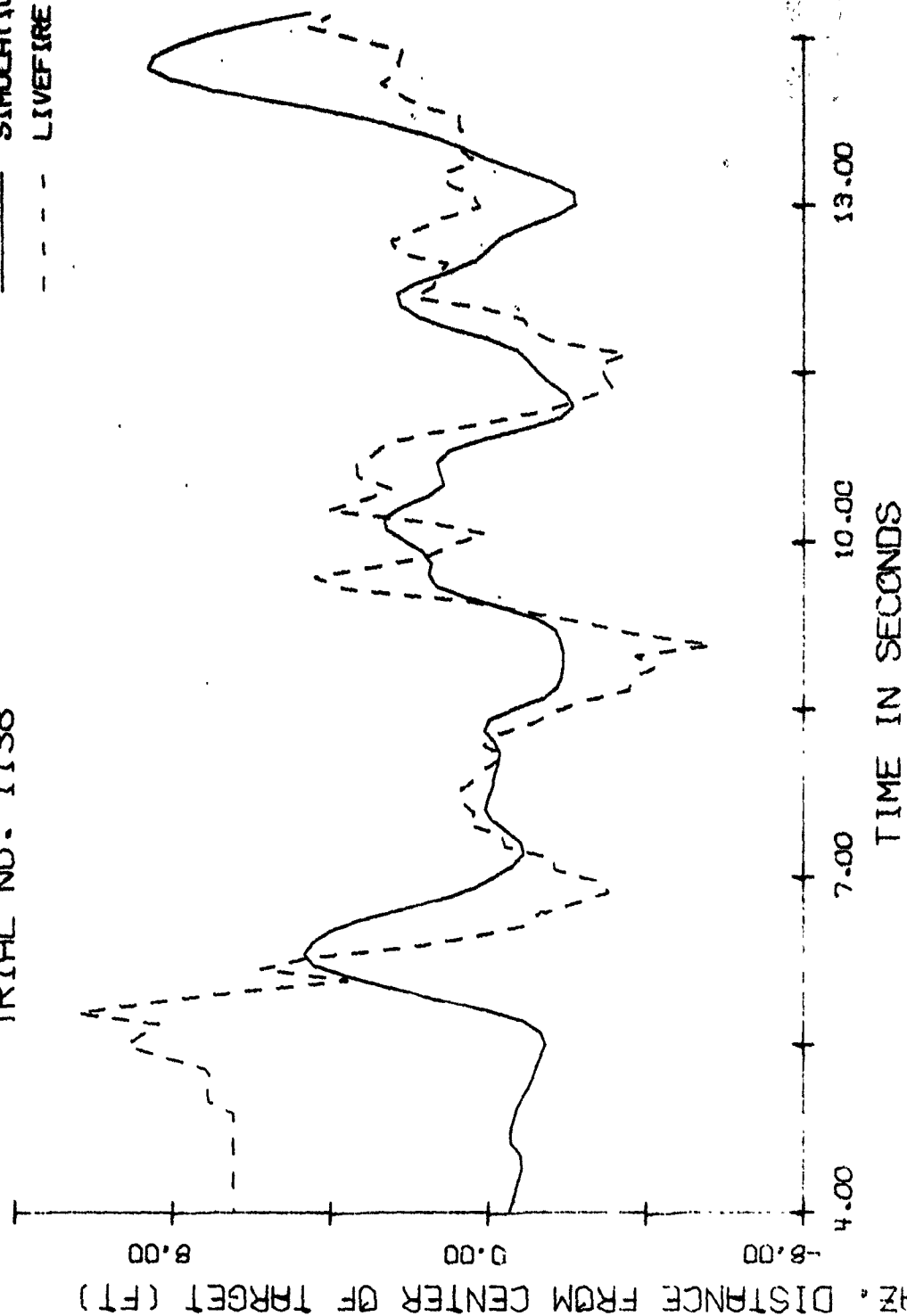
TARGET RANGE - 2855 METERS
TRIAL NO. 1138

— SIMULATION
- - - LIVEFIRE



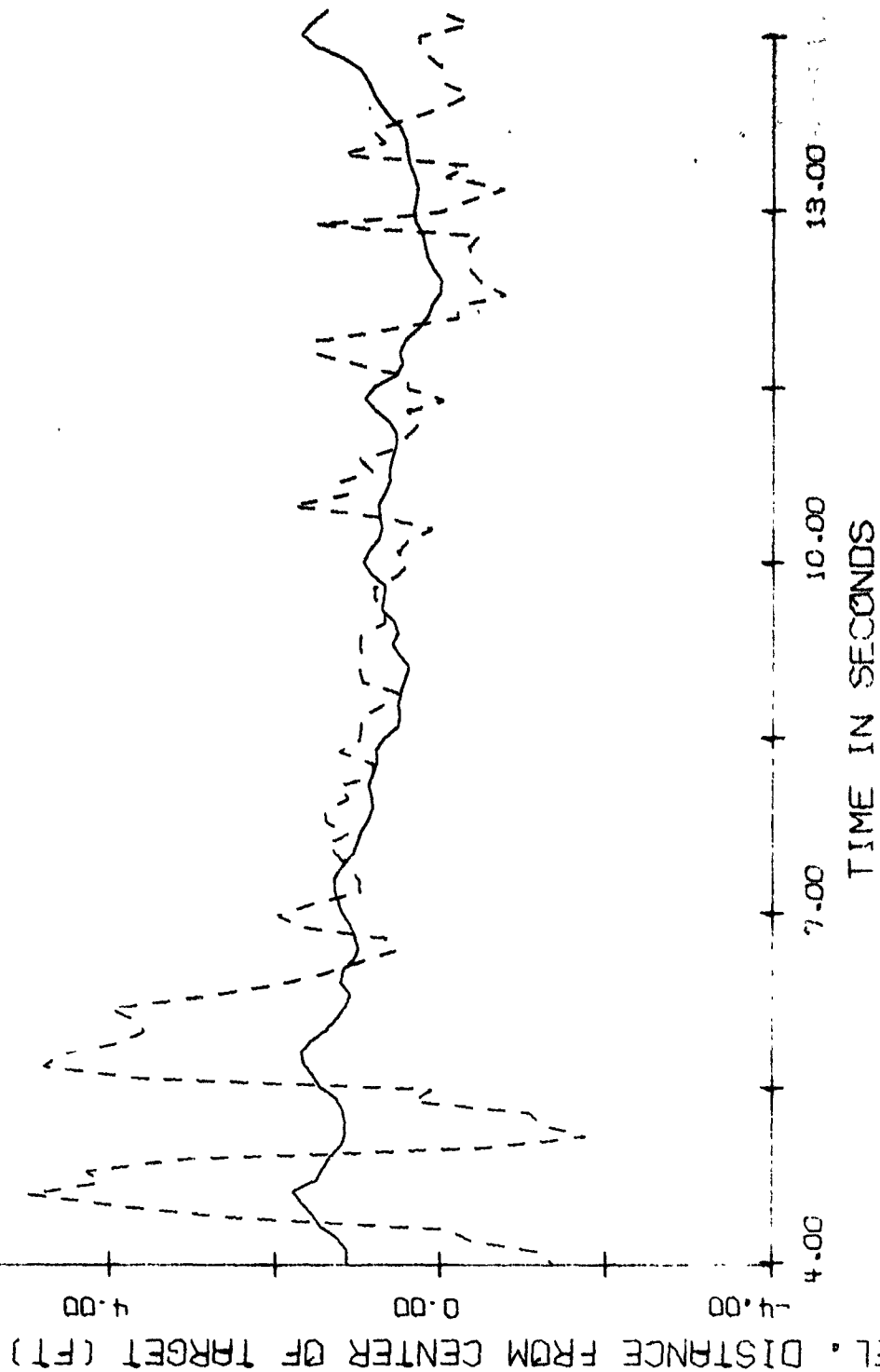
TARGET RANGE - 2855 METERS
TRIAL NO. 1138

— SIMULATION
--- LIVEFIRE



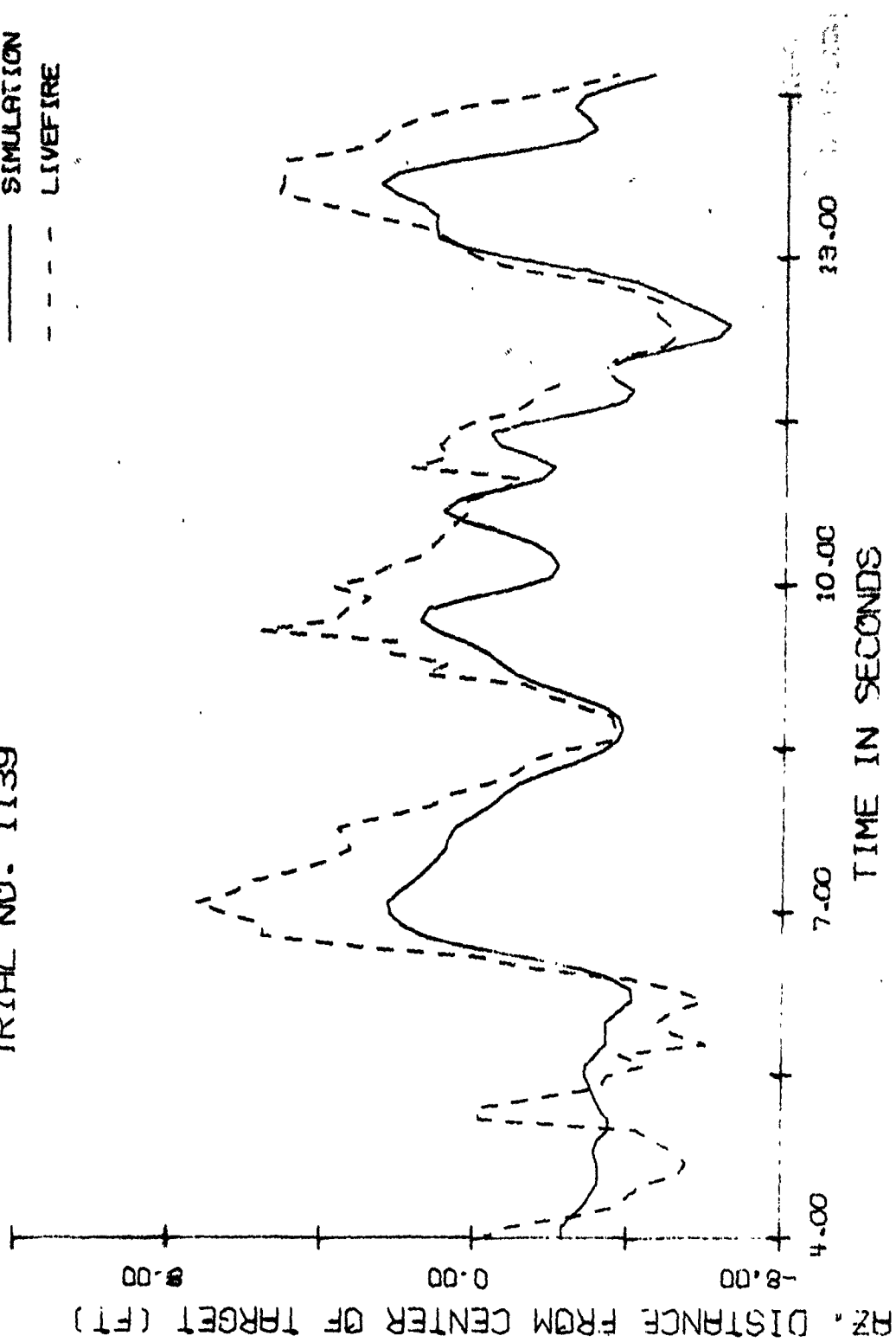
TARGET RANGE - 2855 METERS
TRIAL NO. 1139

— SIMULATION
- - - LIVEFIRE



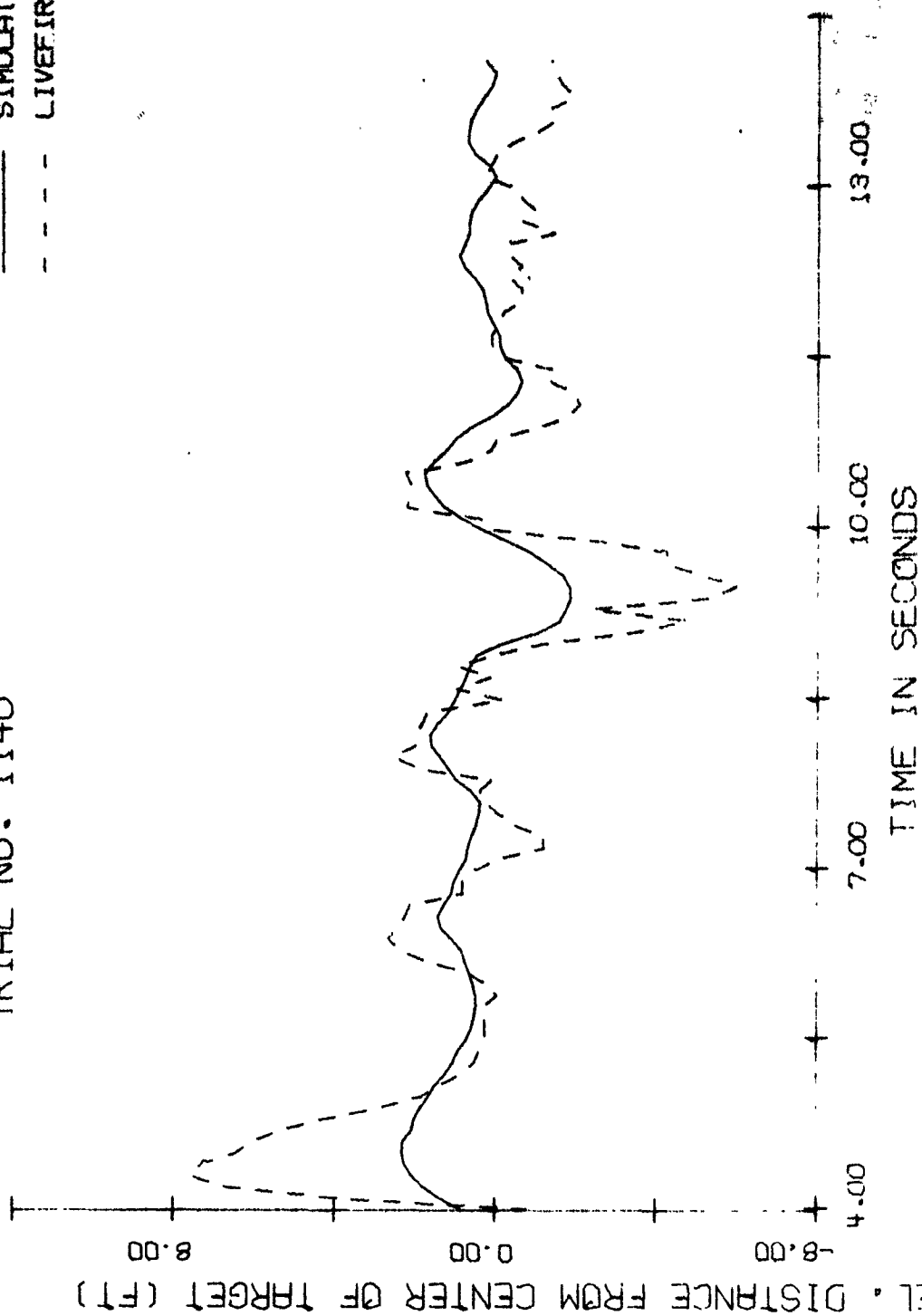
TARGET RANGE - 2855 METERS
TRIAL NO. 1139

— SIMULATION
- - - LIVEFIRE



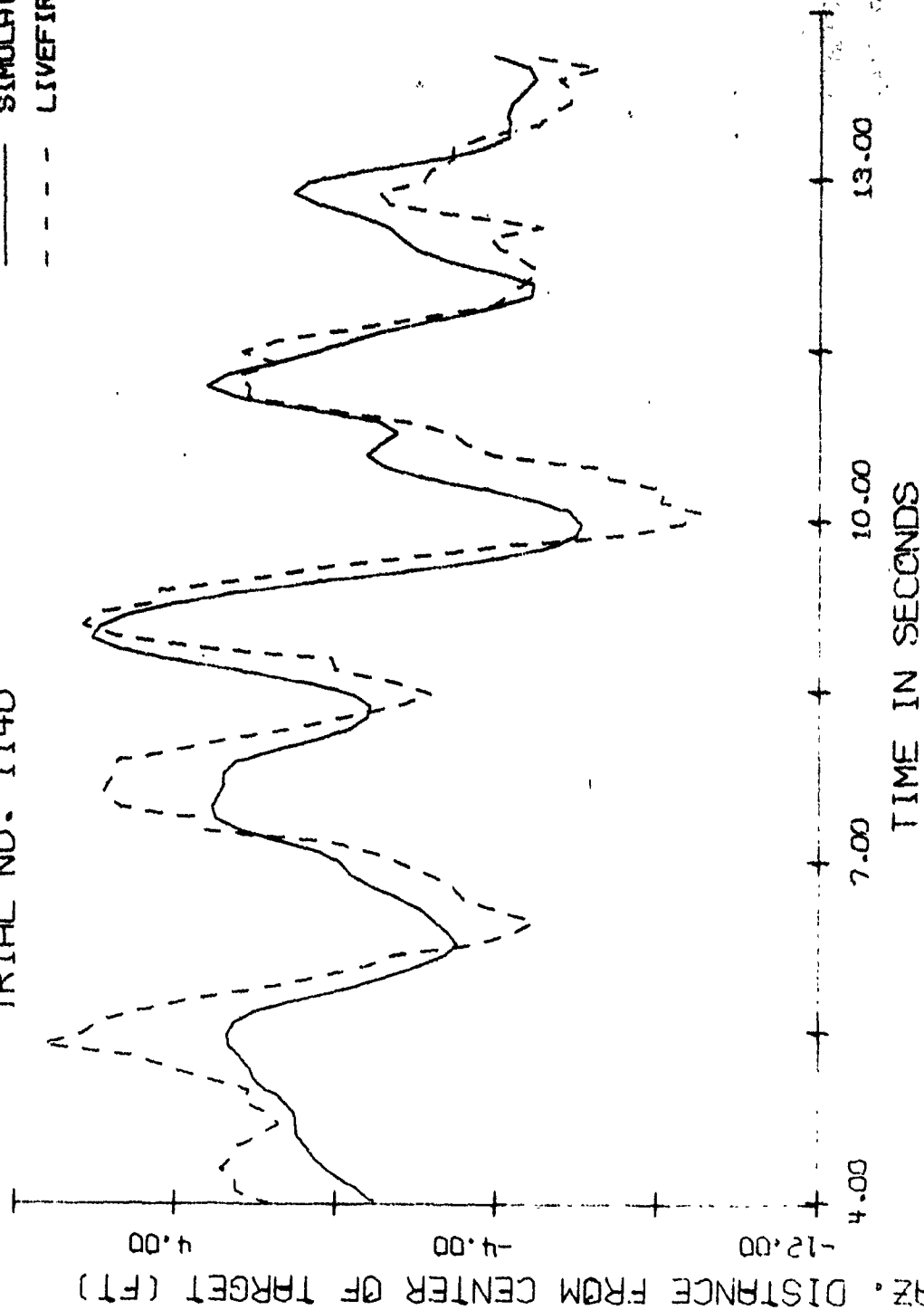
TARGET RANGE - 2855 METERS
TRIAL NO. 1140

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1140

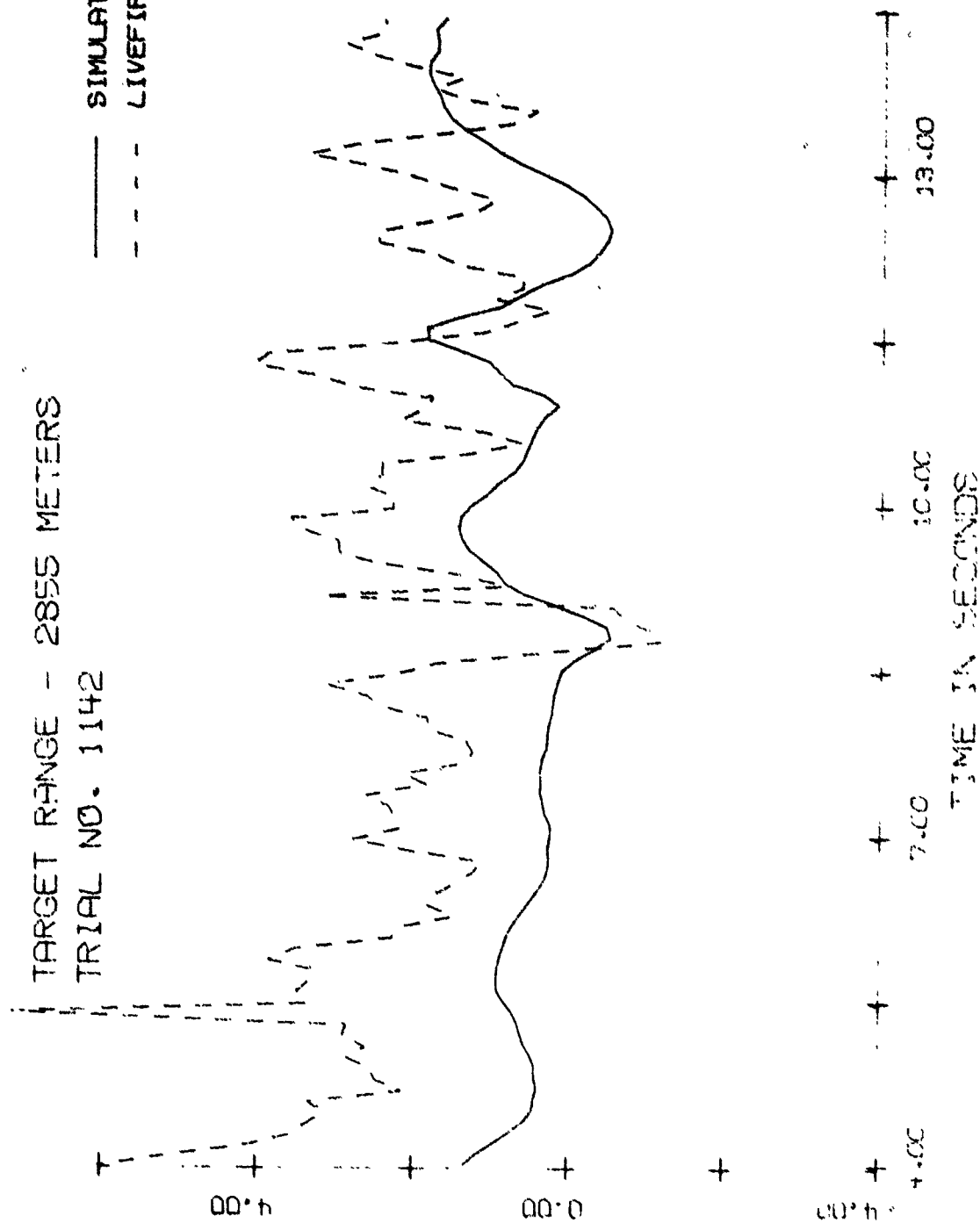
— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
 TRIAL NO. 1142

— SIMULATION
 --- LIVEFIRE

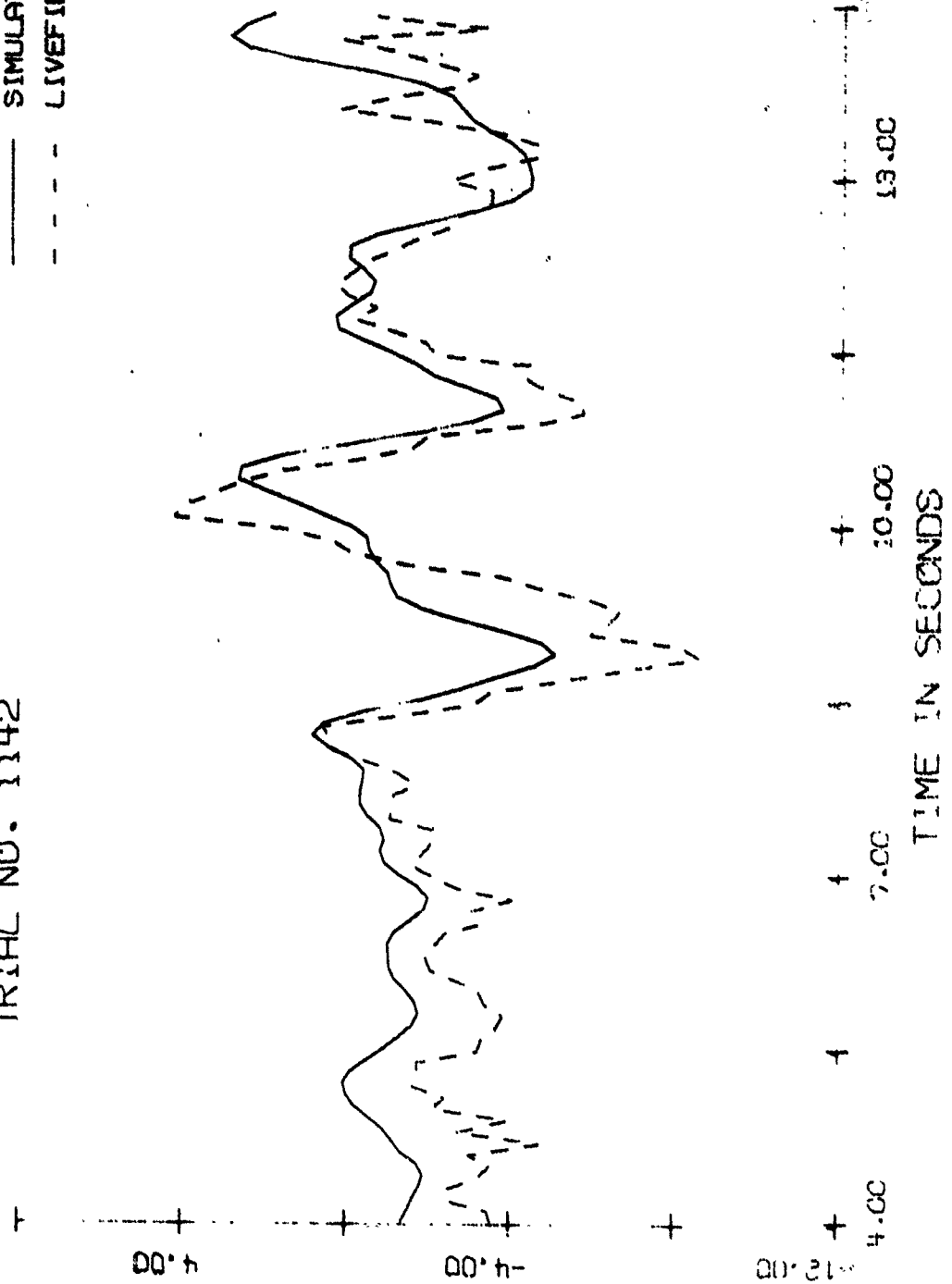
FT. DISTANCE FROM CENTER OF TARGET (FT)



RZ, DISTANCE FROM CENTER OF TARGET (FT)

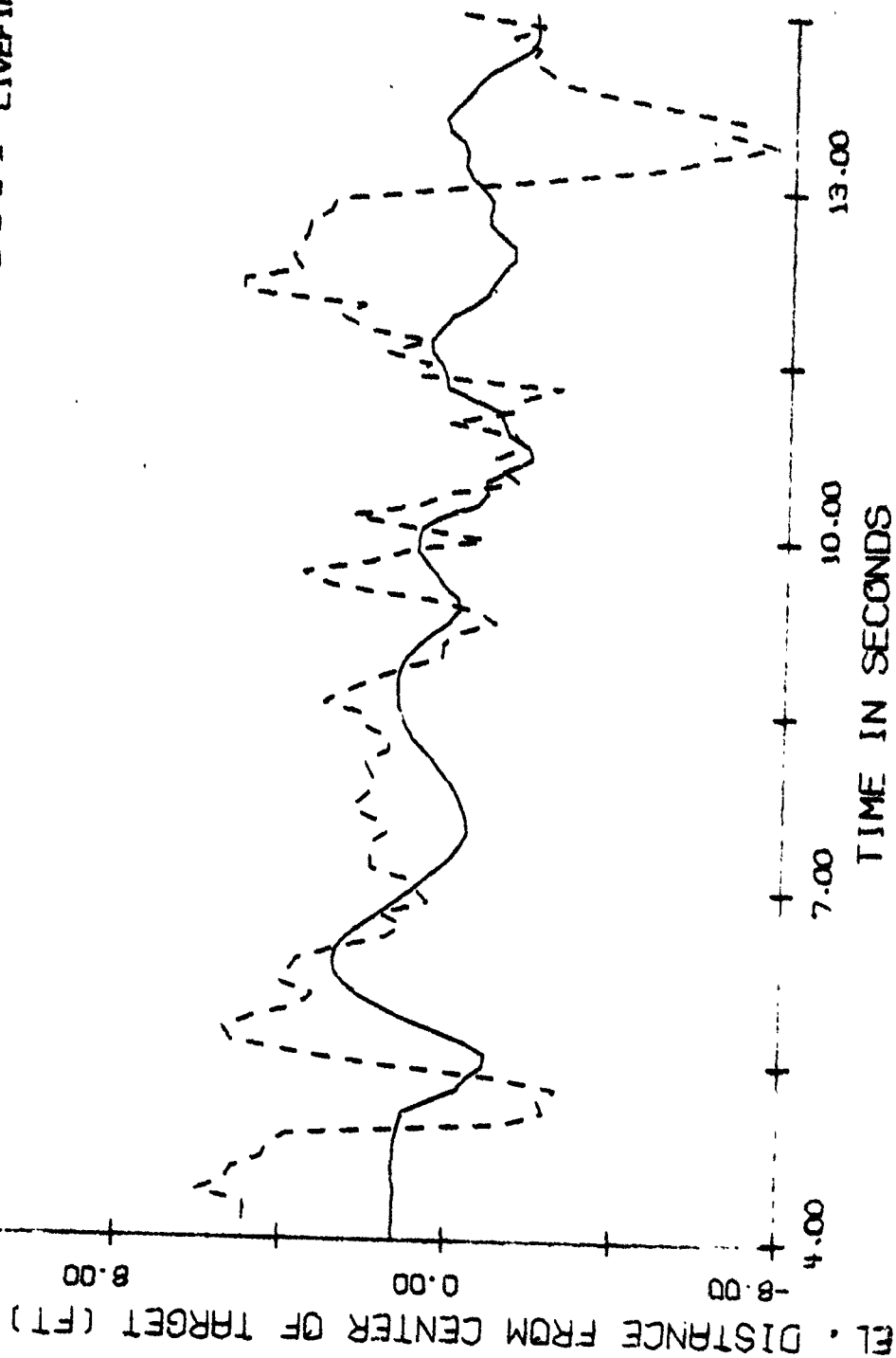
— SIMULATION
- - - LIVEFIRE

TARGET RANGE - 2855 METERS
TRIAL NO. 1142



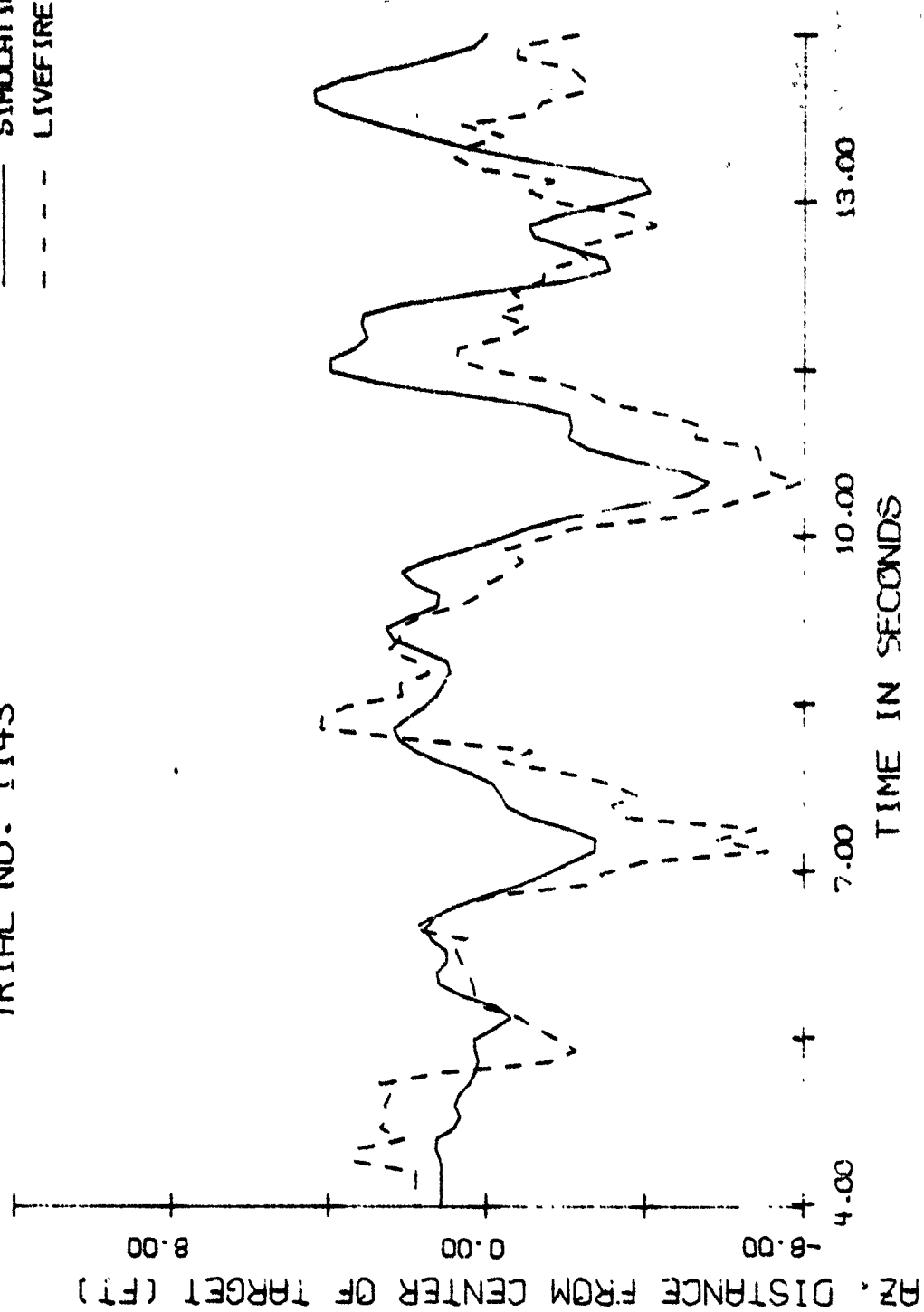
TARGET RANGE - 2855 METERS
TRIAL NO. 1143

— SIMULATION
- - - LIVEFIRE



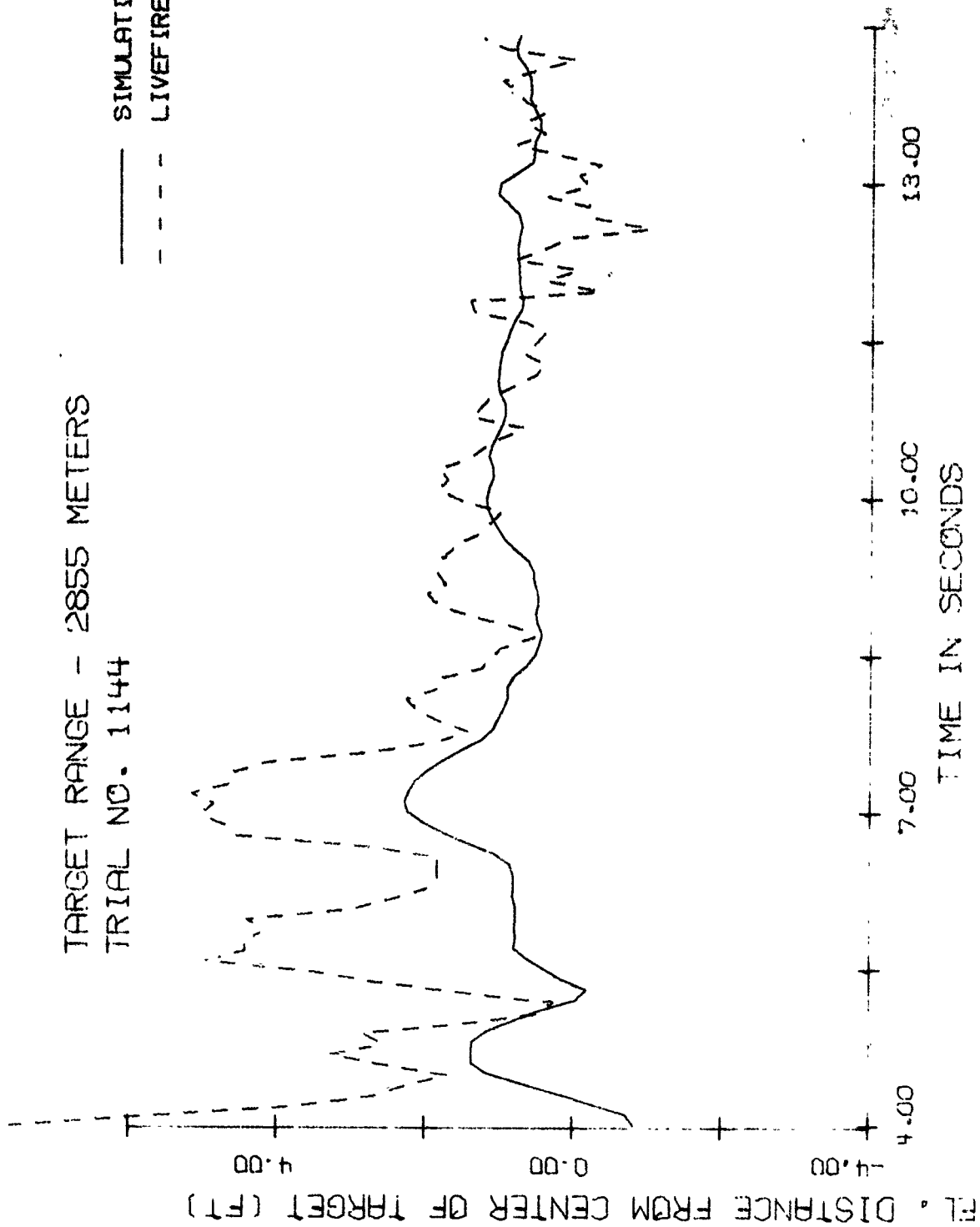
TARGET RANGE - 2855 METERS
TRIAL NO. 1143

— SIMULATION
- - - LIVEFIRE



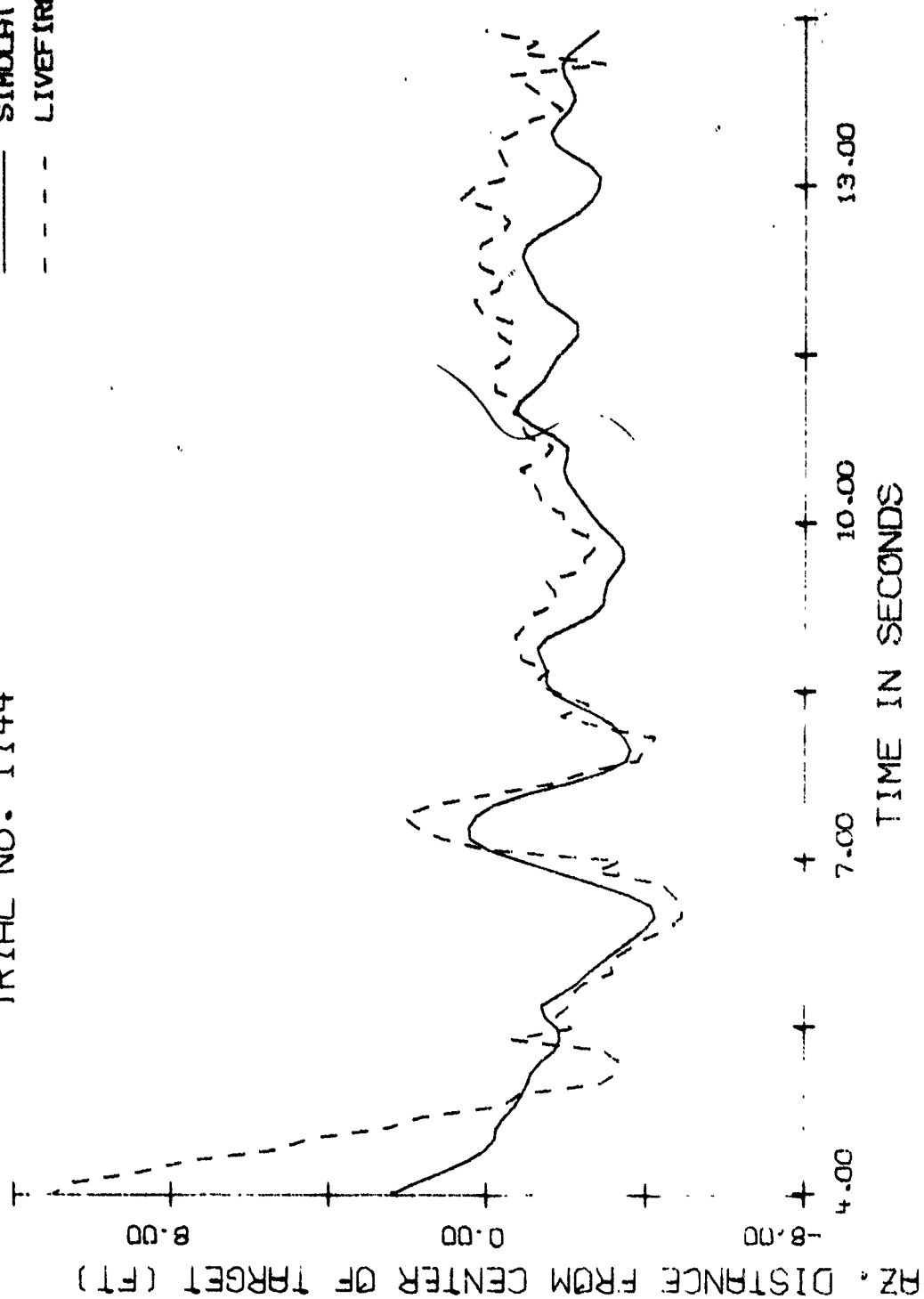
TARGET RANGE - 2855 METERS
 TRIAL NO. 1144

— SIMULATION
 - - - LIVEFIRE



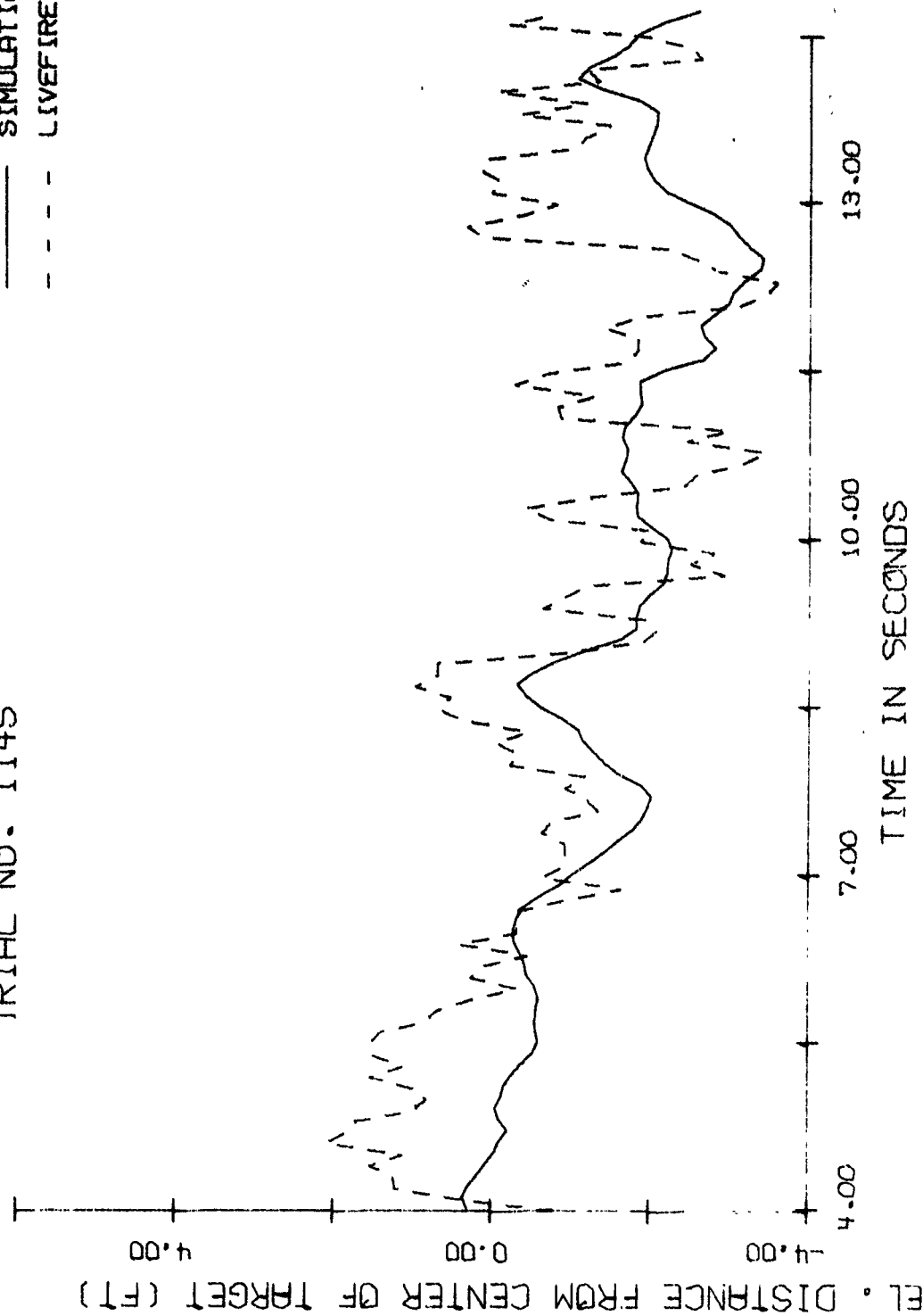
TARGET RANGE - 2855 METERS
TRIAL NO. 1144

— SIMULATION
- - - LIVEFIRE



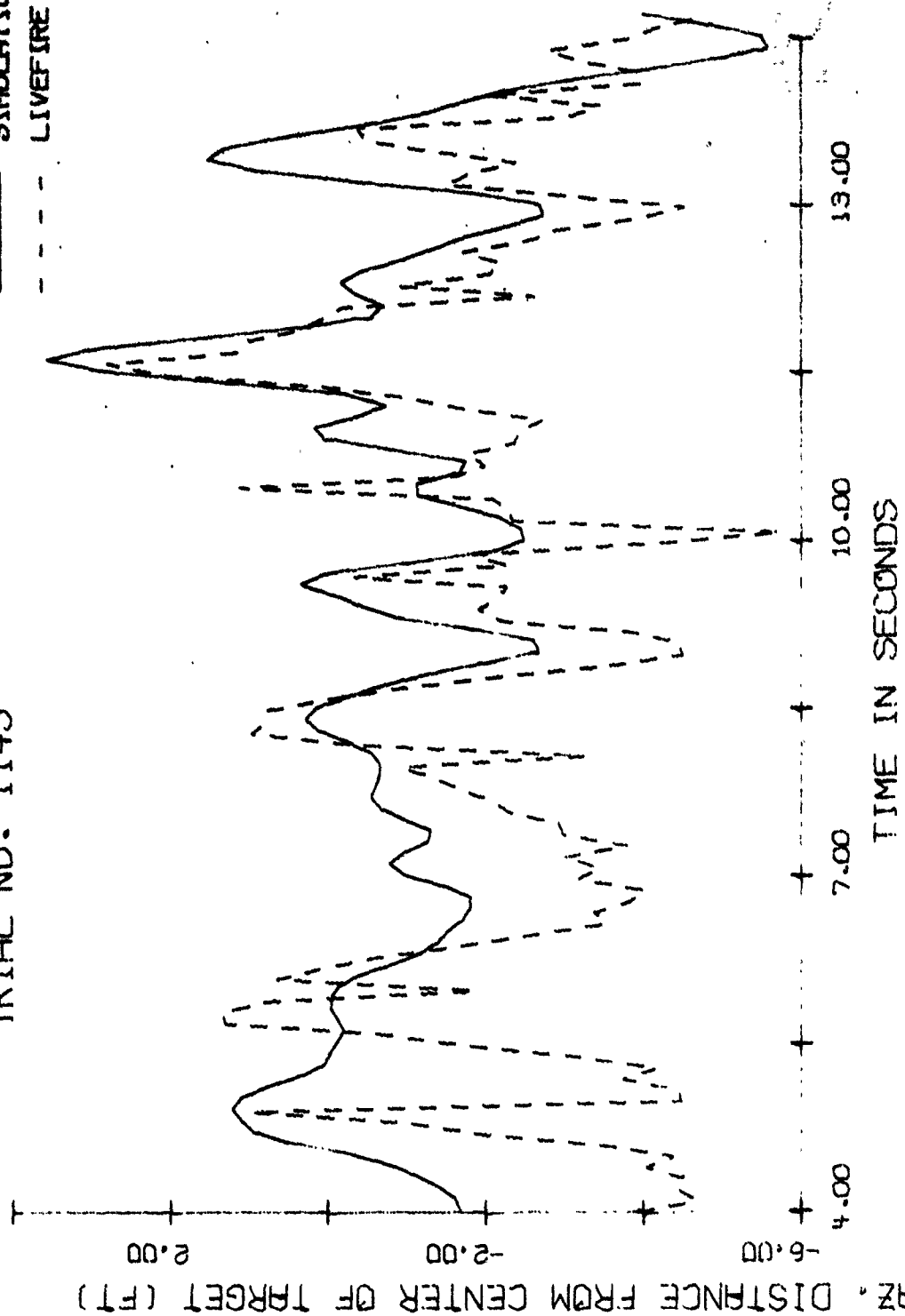
TARGET RANGE - 2855 METERS
TRIAL NO. 1145

— SIMULATION
- - - LIVEFIRE



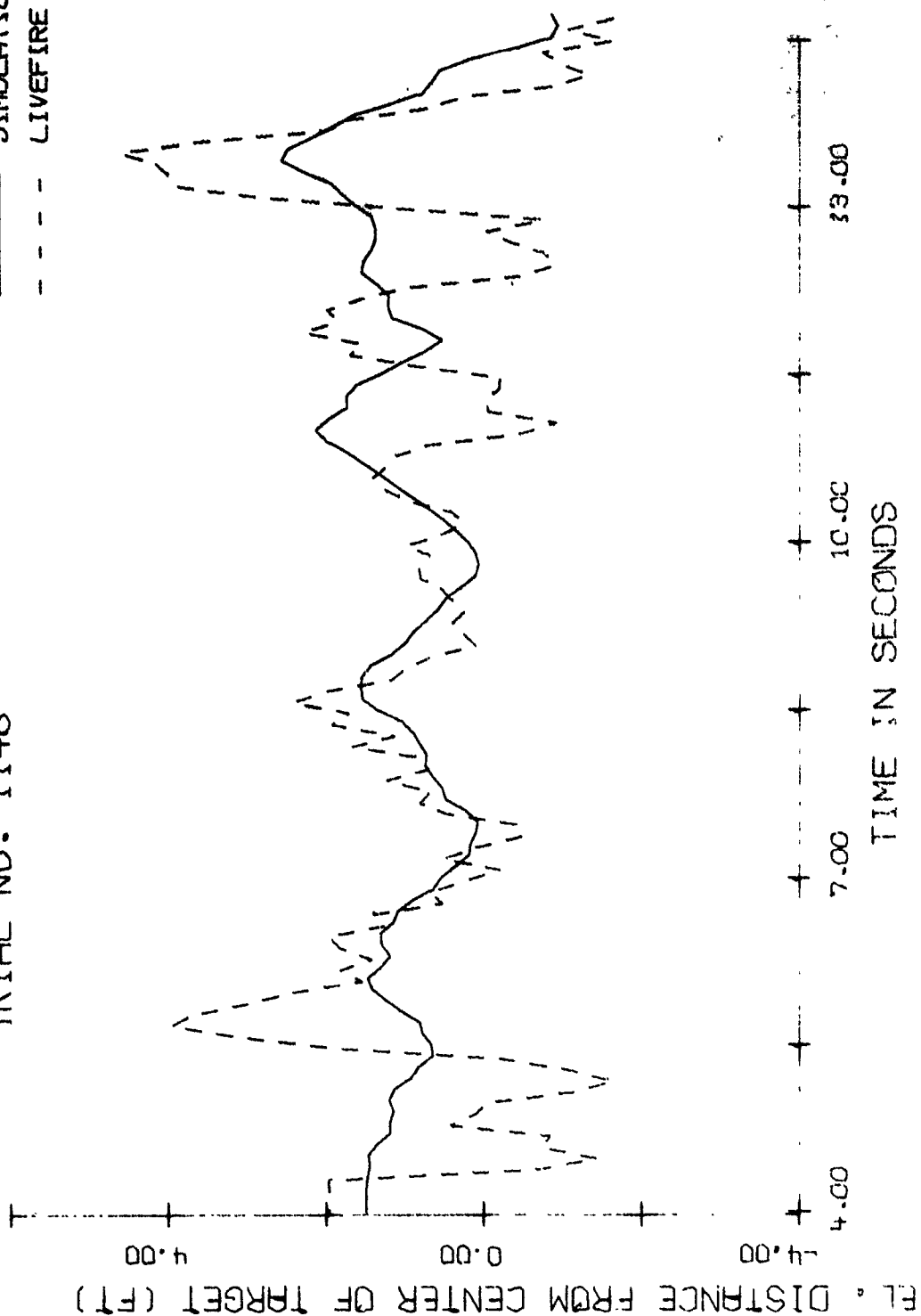
TARGET RANGE - 2855 METERS
TRIAL NO. 1145

— SIMULATION
- - - LIVEFIRE



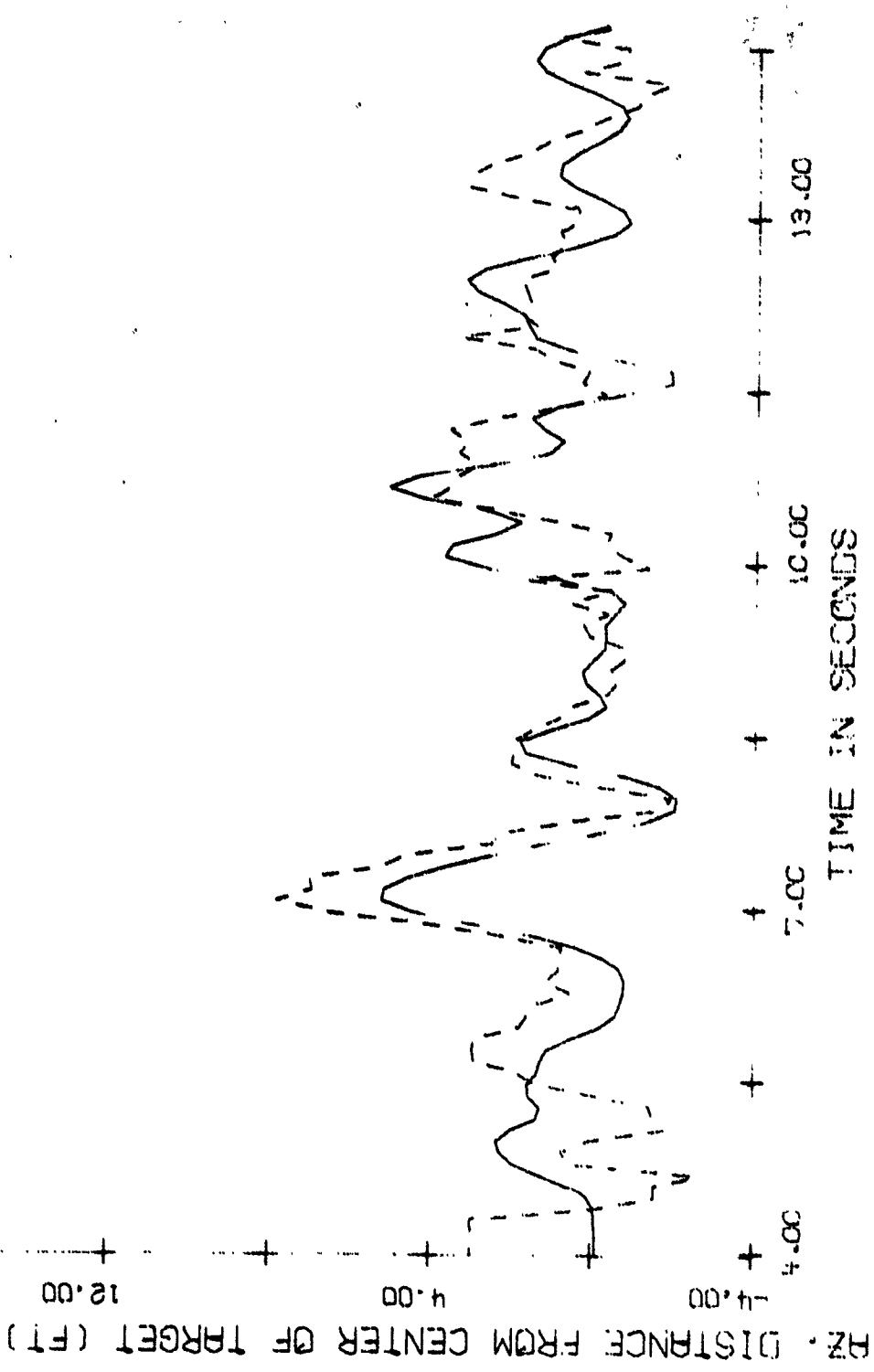
TARGET RANGE - 2855 METERS
 TRIAL NO. 1146

— SIMULATION
 - - - LIVEFIRE



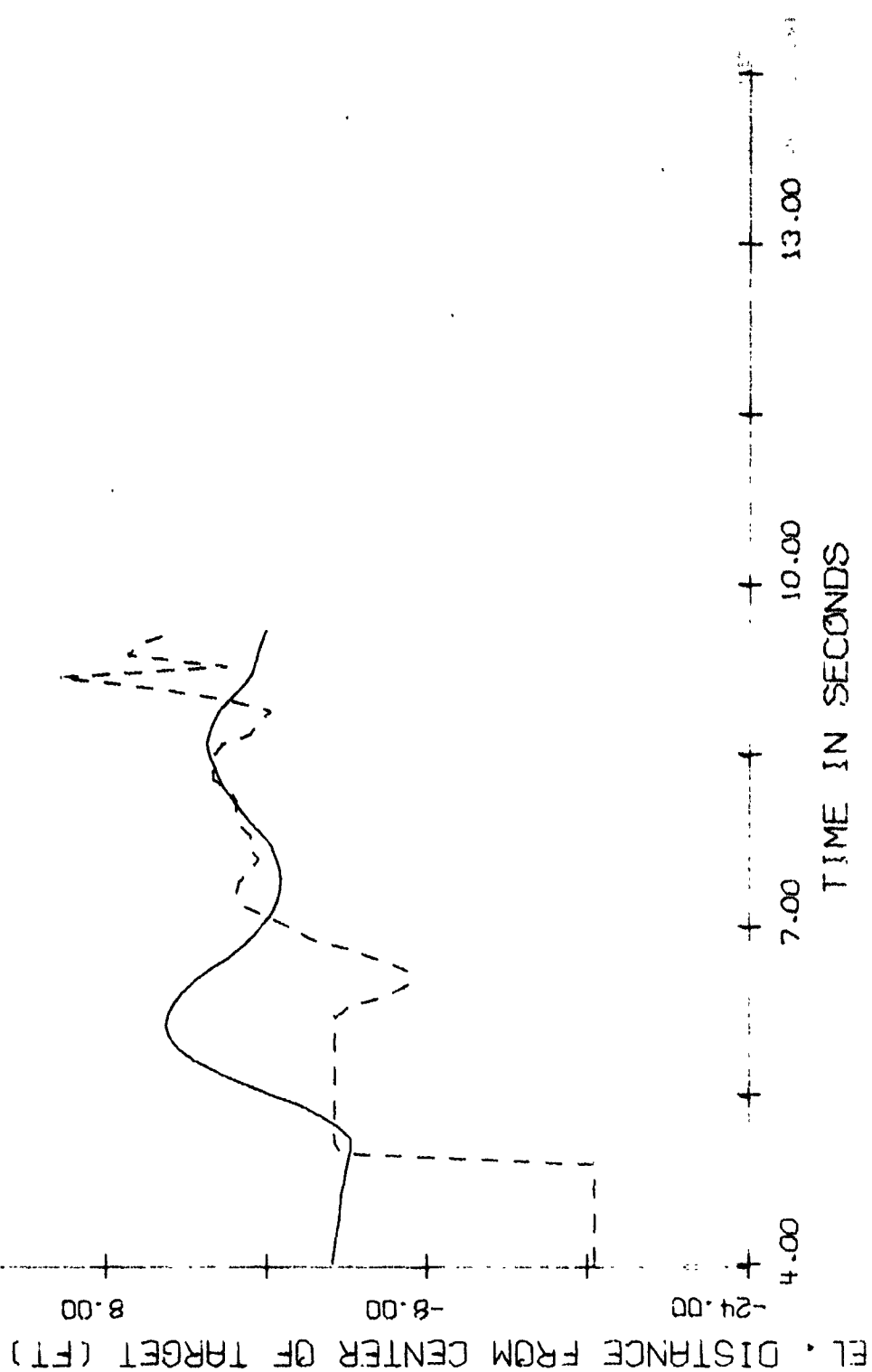
TARGET RANGE - 2855 METERS
TRIAL NO. 1146

— SIMULATION
- - - LIVEFIRE



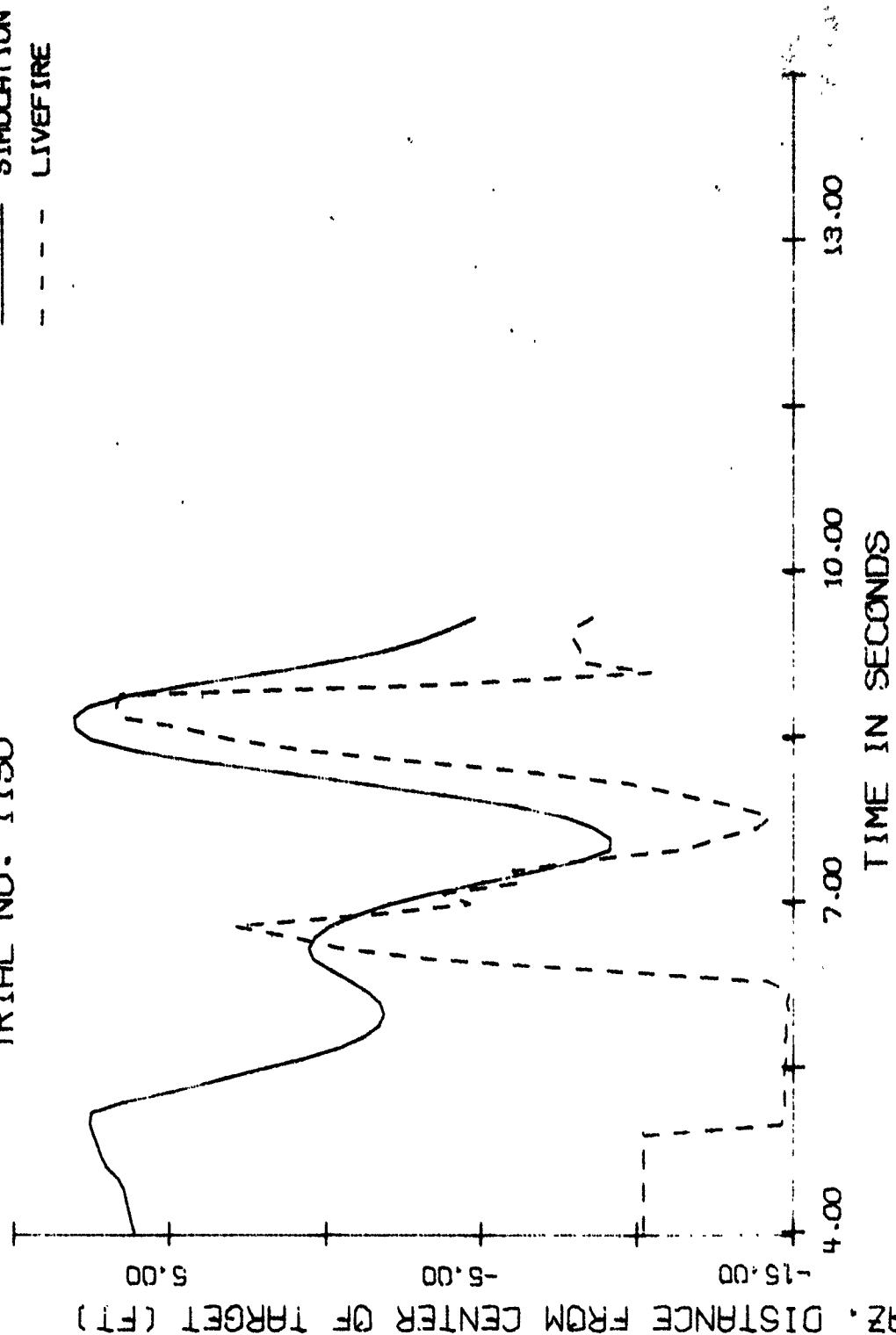
TARGET RANGE - 2855 METERS
 TRIAL NO. 1150

— SIMULATION
 - - - LIVEFIRE



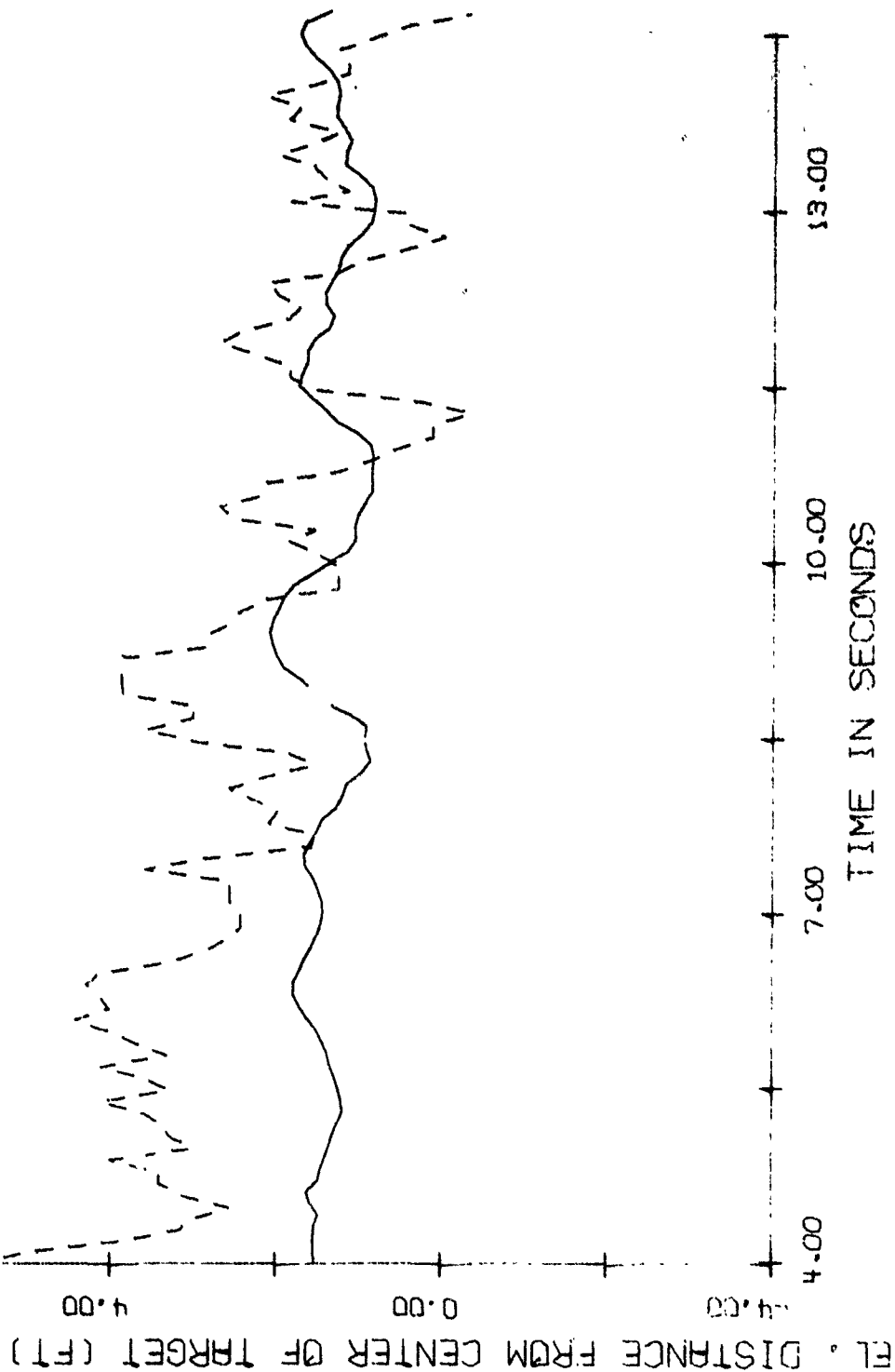
TARGET RANGE - 2855 METERS
TRIAL NO. 1150

— SIMULATION
--- LIVEFIRE

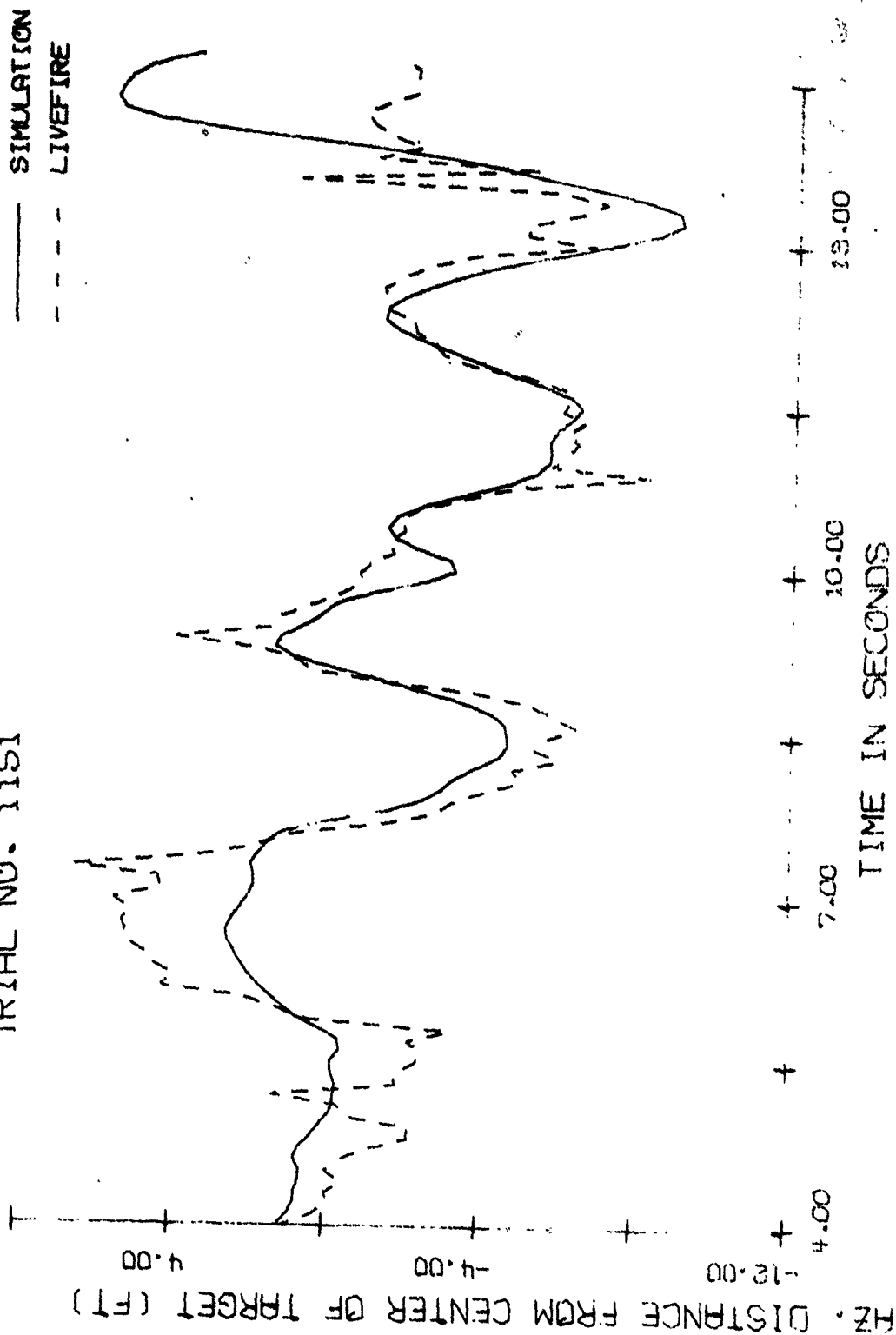


TARGET RANGE - 2855 METERS
 TRIAL NO. 1151

— SIMULATION
 - - - LIVEFIRE



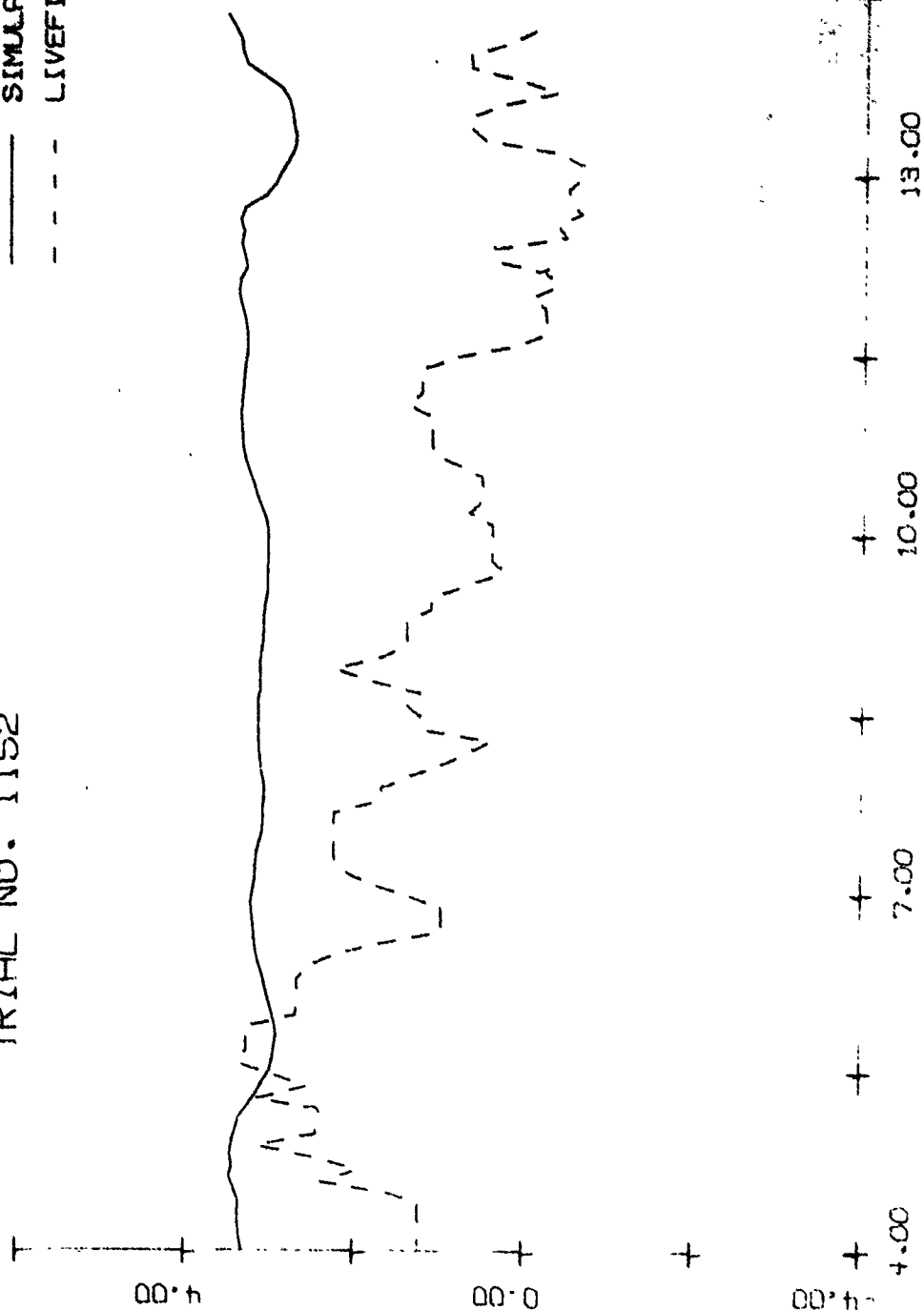
TARGET RANGE - 2855 METERS
 TRIAL NO. 1151



TARGET RANGE - 2855 METERS
 TRIAL NO. 1152

— SIMULATION
 - - - LIVEFIRE

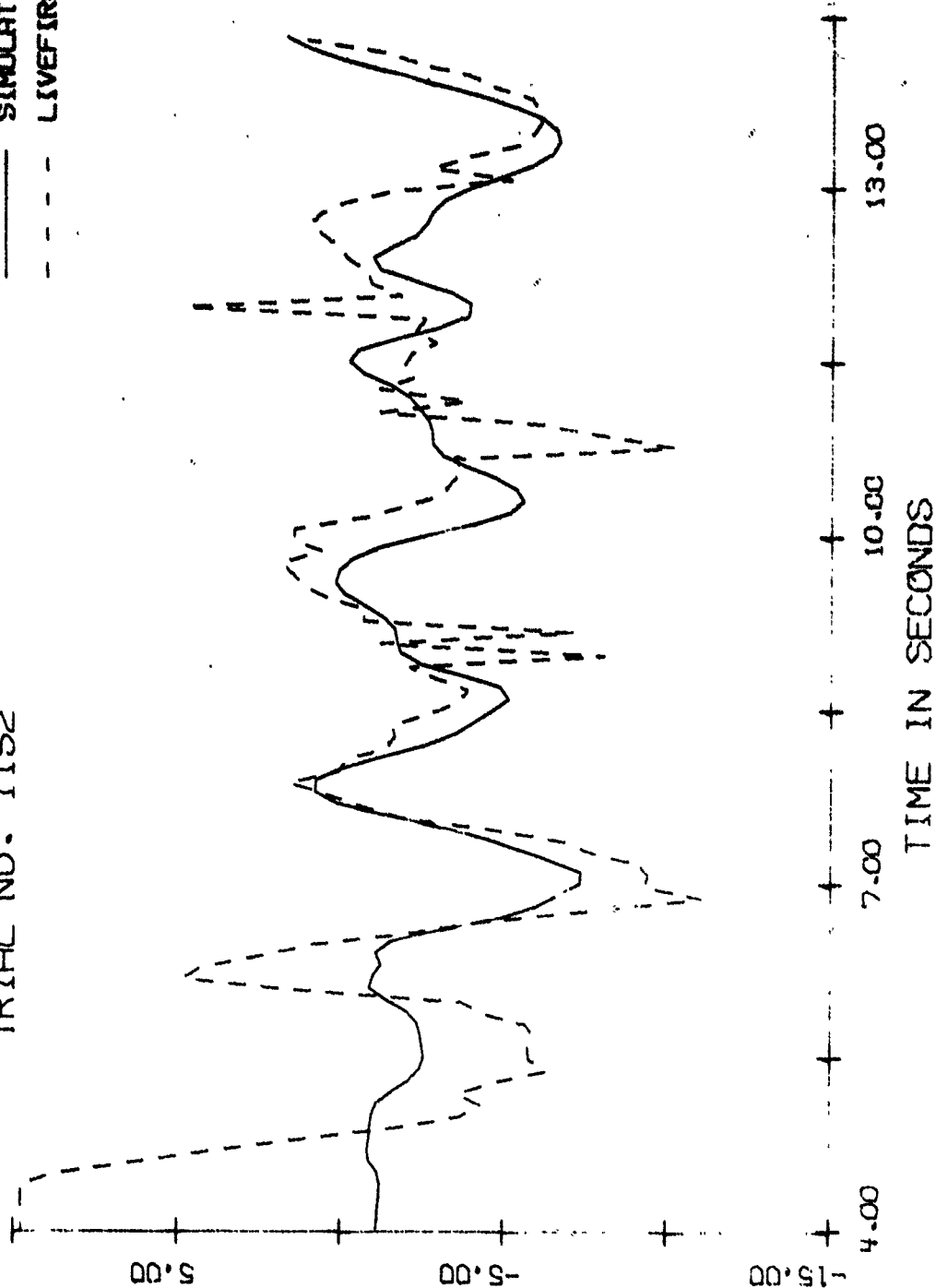
FL - DISTANCE FROM CENTER OF TARGET (FT)



TARGET RANGE - 2855 METERS
TRIAL NO. 1152

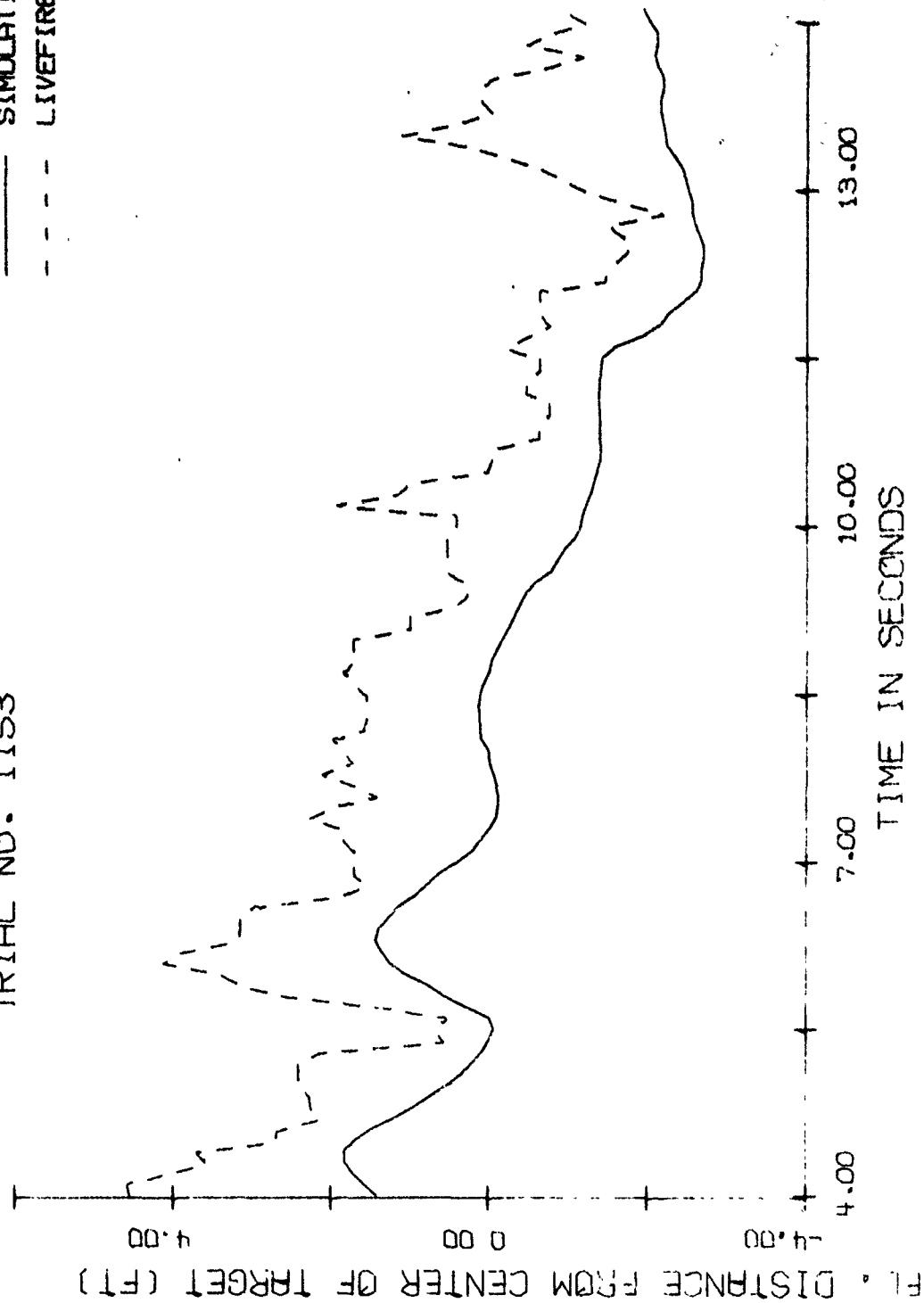
— SIMULATION
- - - LIVEFIRE

AX, DISTANCE FROM CENTER OF TARGET (FT)



TARGET RANGE - 2855 METERS
 TRIAL NO. 1153

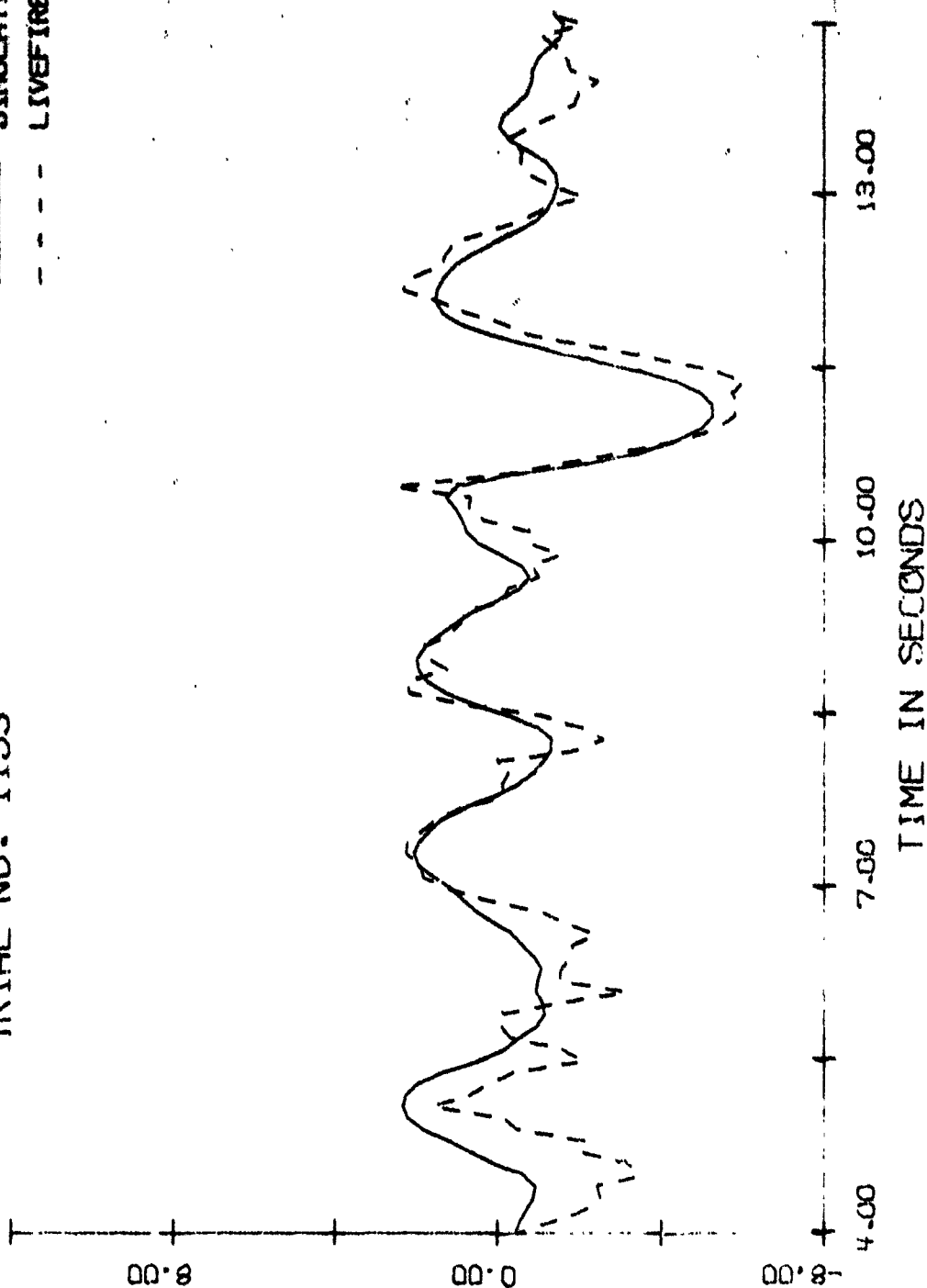
— SIMULATION
 - - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1153

— SIMULATION
- - - LIVEFIRE

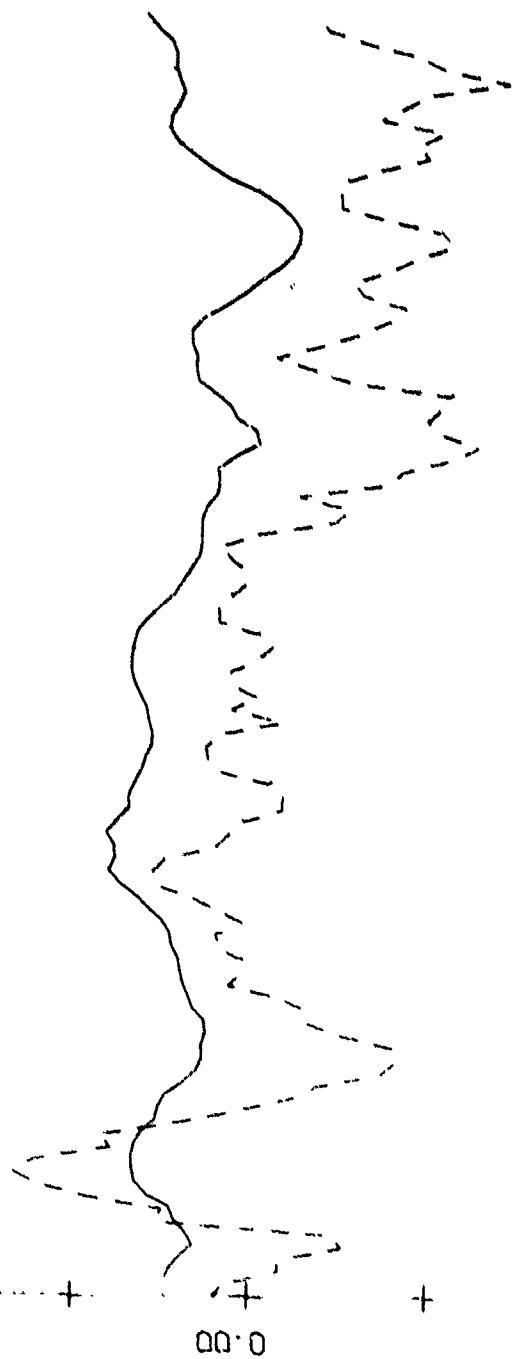
AZ. DISTANCE FROM CENTER OF TARGET (FT)



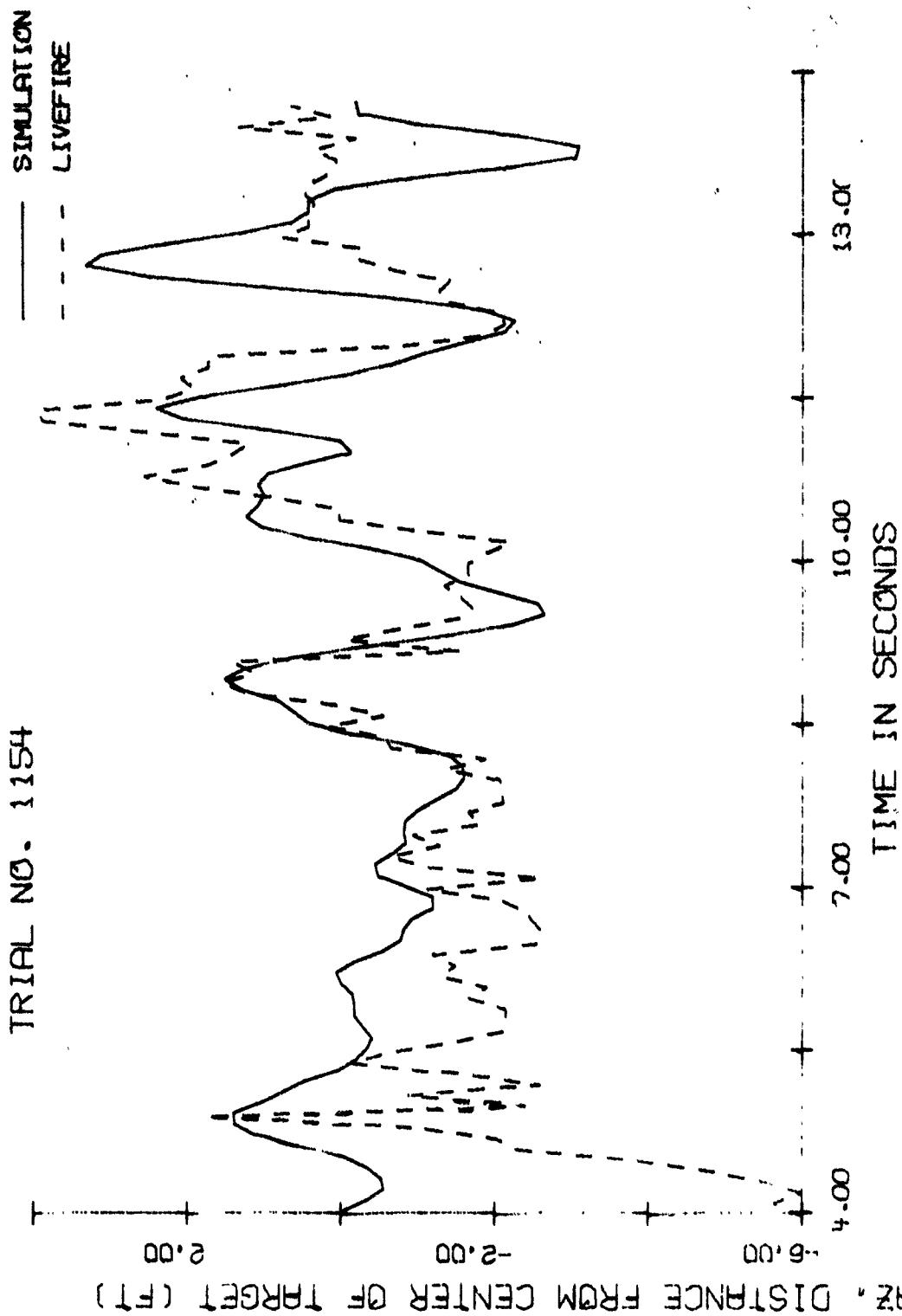
TARGET RANGE - 2855 METERS
 TRIAL NO. 1154

— SIMULATION
 - - - LIVEFIRE

FL. DISTANCE FROM CENTER OF TARGET (FT)



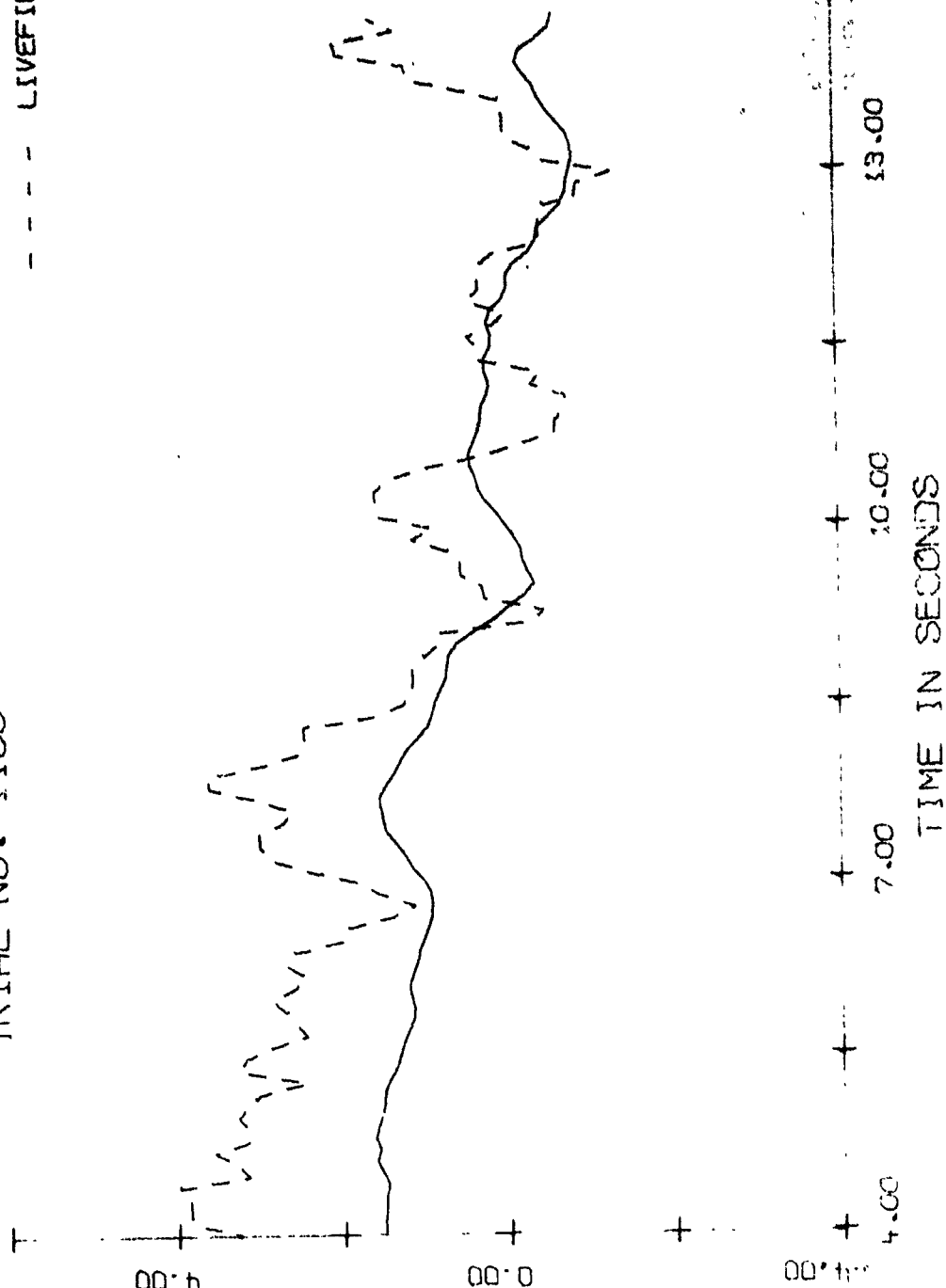
TARGET RANGE - 2855 METERS
 TRIAL NO. 1154



TARGET RANGE - 2855 METERS
TRIAL NO. 1155

— SIMULATION
- - - LIVEFIRE

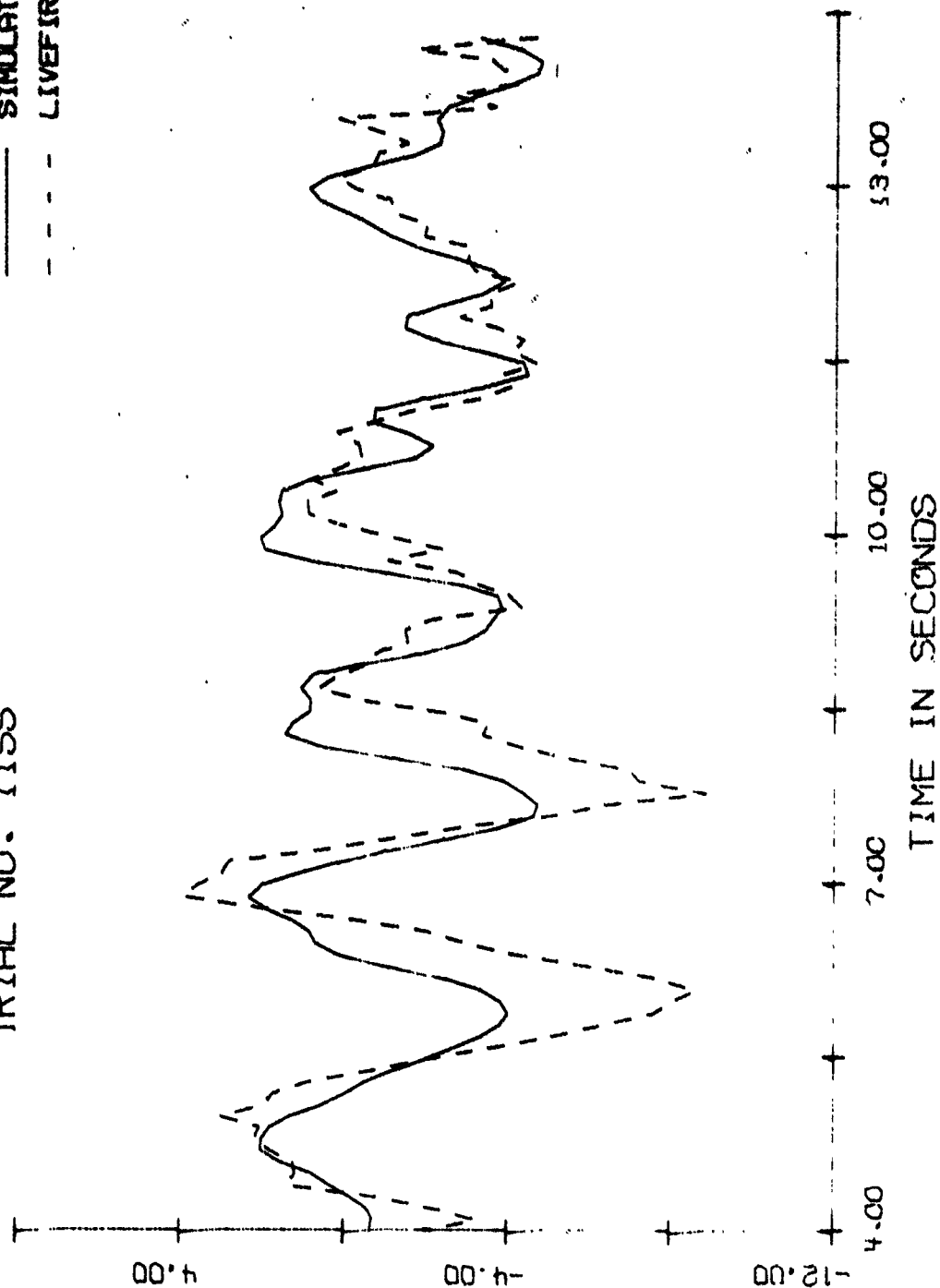
EL. DISTANCE FROM CENTER OF TARGET (FT)



AZ, DISTANCE FROM CENTER OF TARGET (FT)

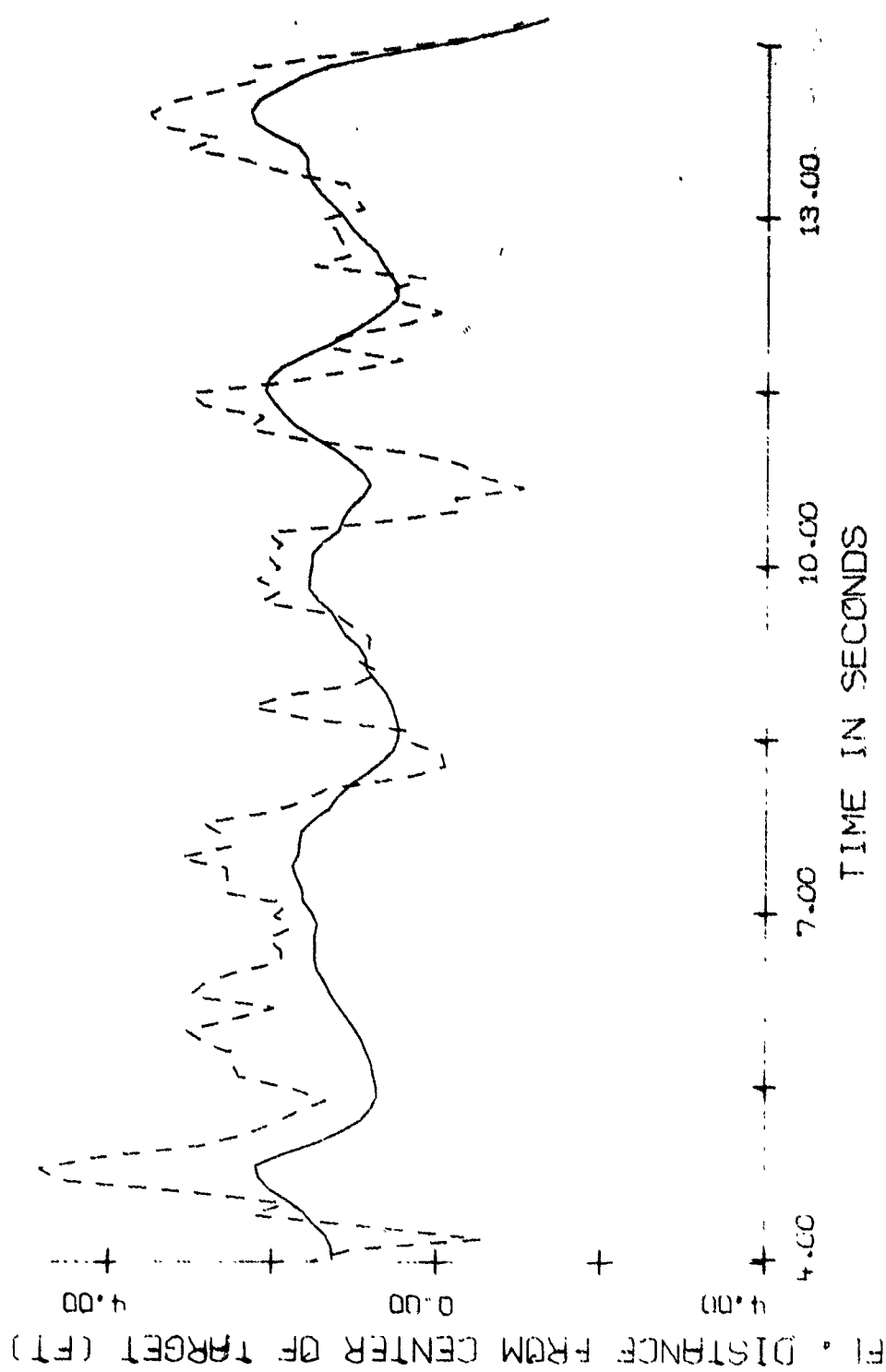
— SIMULATION
- - - LIVEFIRE

TARGET RANGE - 2855 METERS
TRIAL NO. 1155



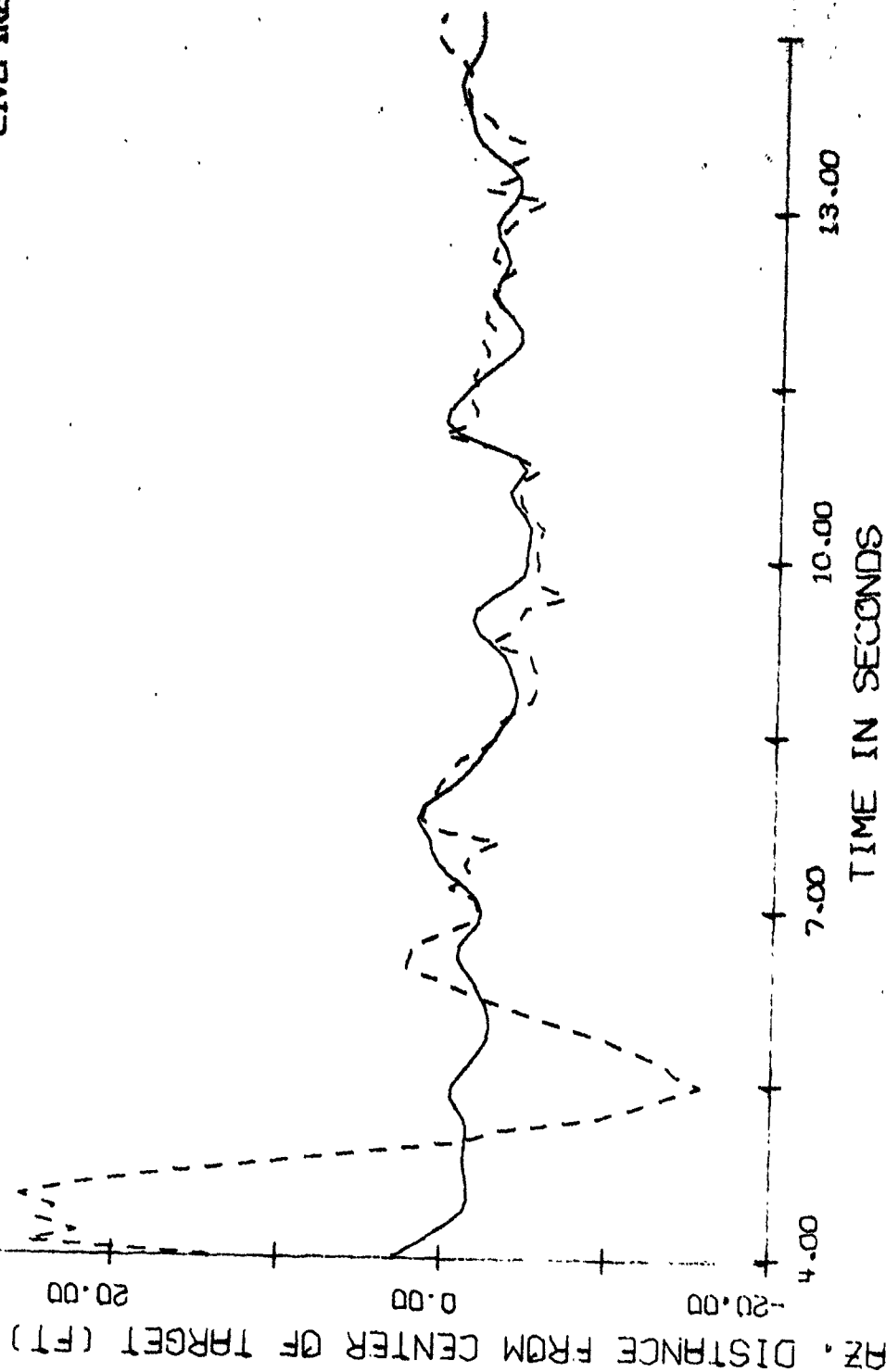
TARGET RANGE - 2855 METERS
 TRIAL NO. 1156

— SIMULATION
 - - - LIVEFIRE



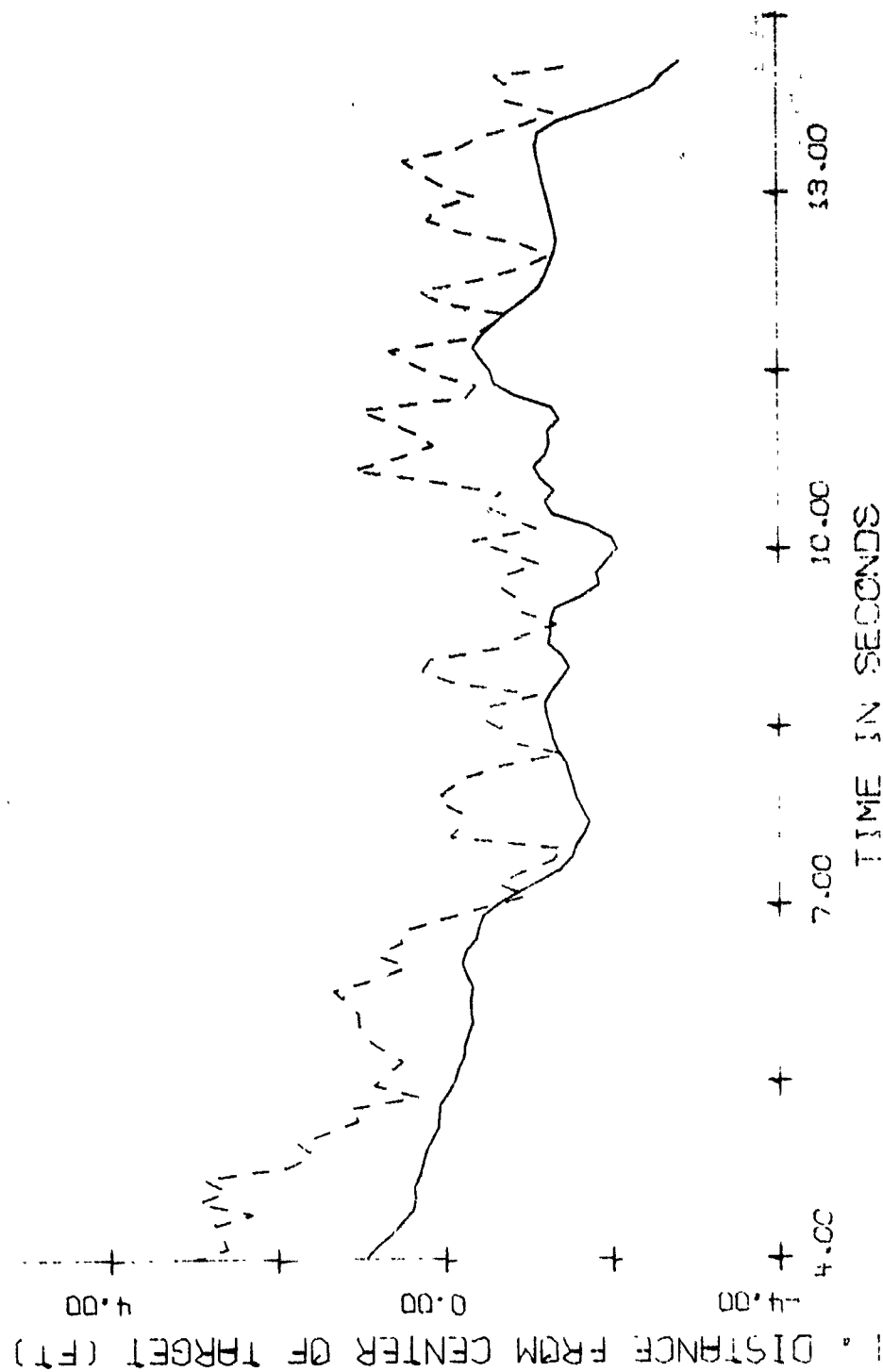
TARGET RANGE - 2855 METERS
TRIAL NO. 1156

— SIMULATION
- - - LIVEFIRE



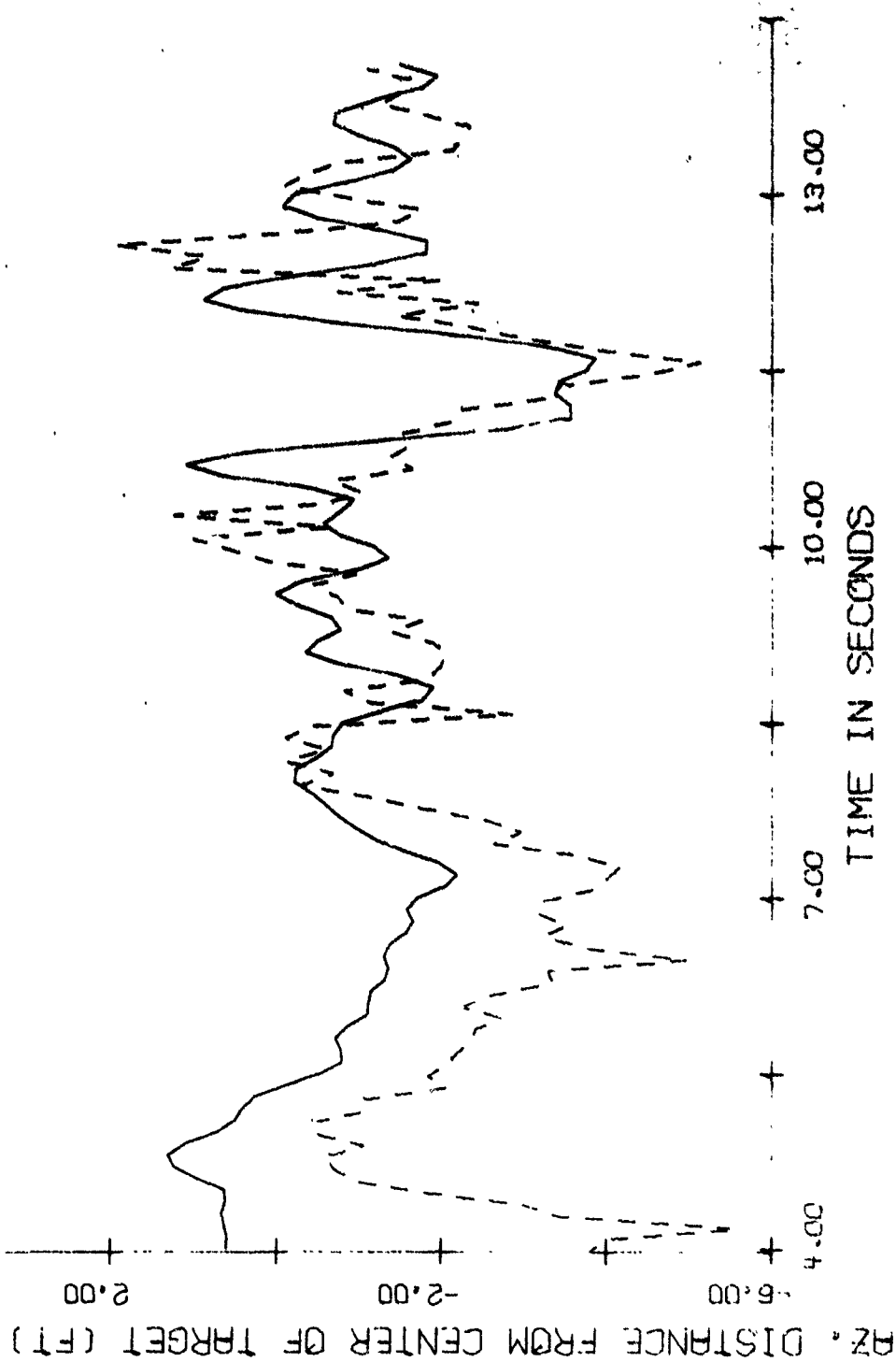
TARGET RANGE - 2855 METERS
 TRIAL NO. 1157

— SIMULATION
 - - - LIVEFIRE



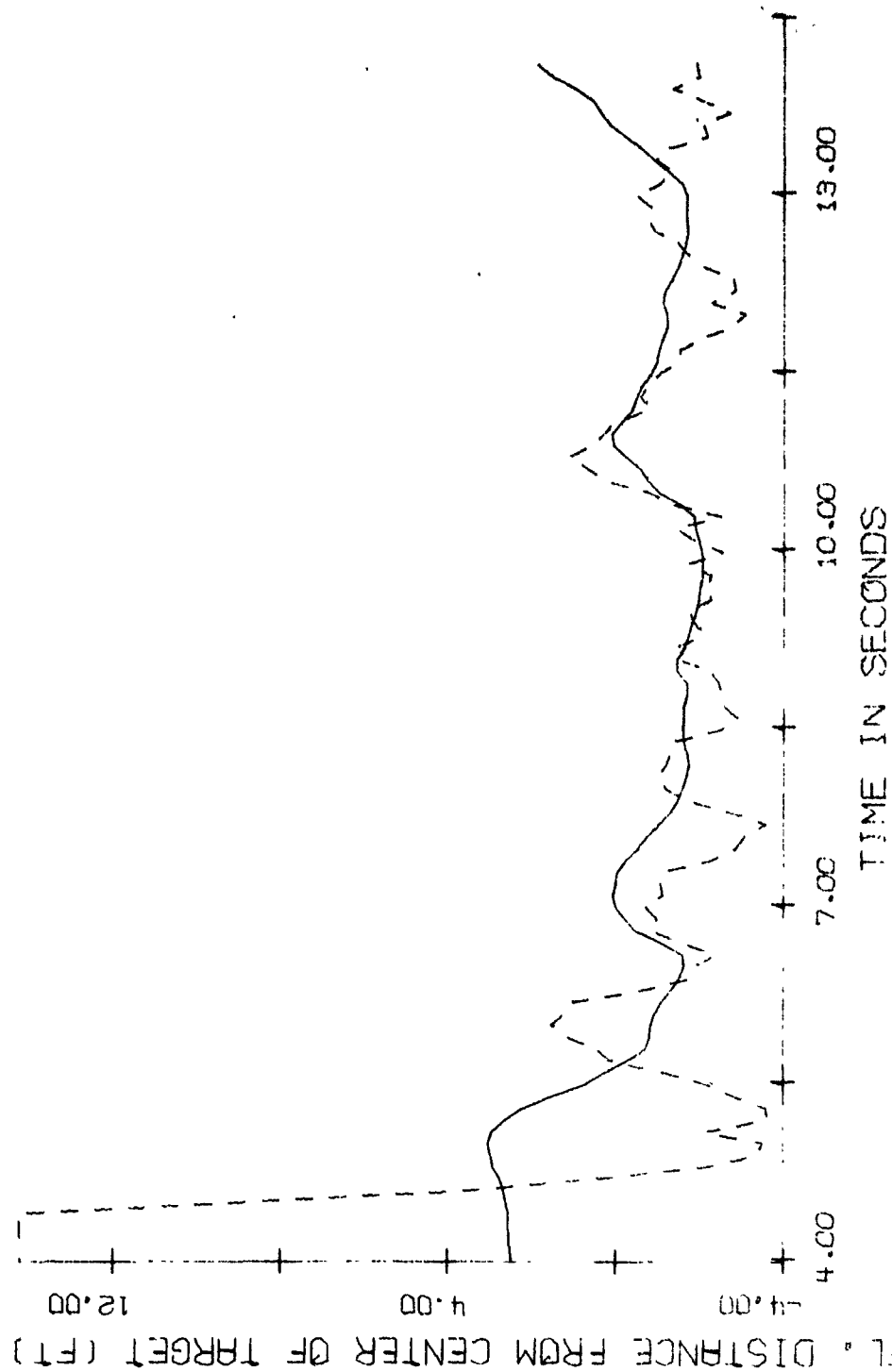
TARGET RANGE - 2855 METERS
 TRIAL NO. 1157

— SIMULATION
 --- LIVEFIRE



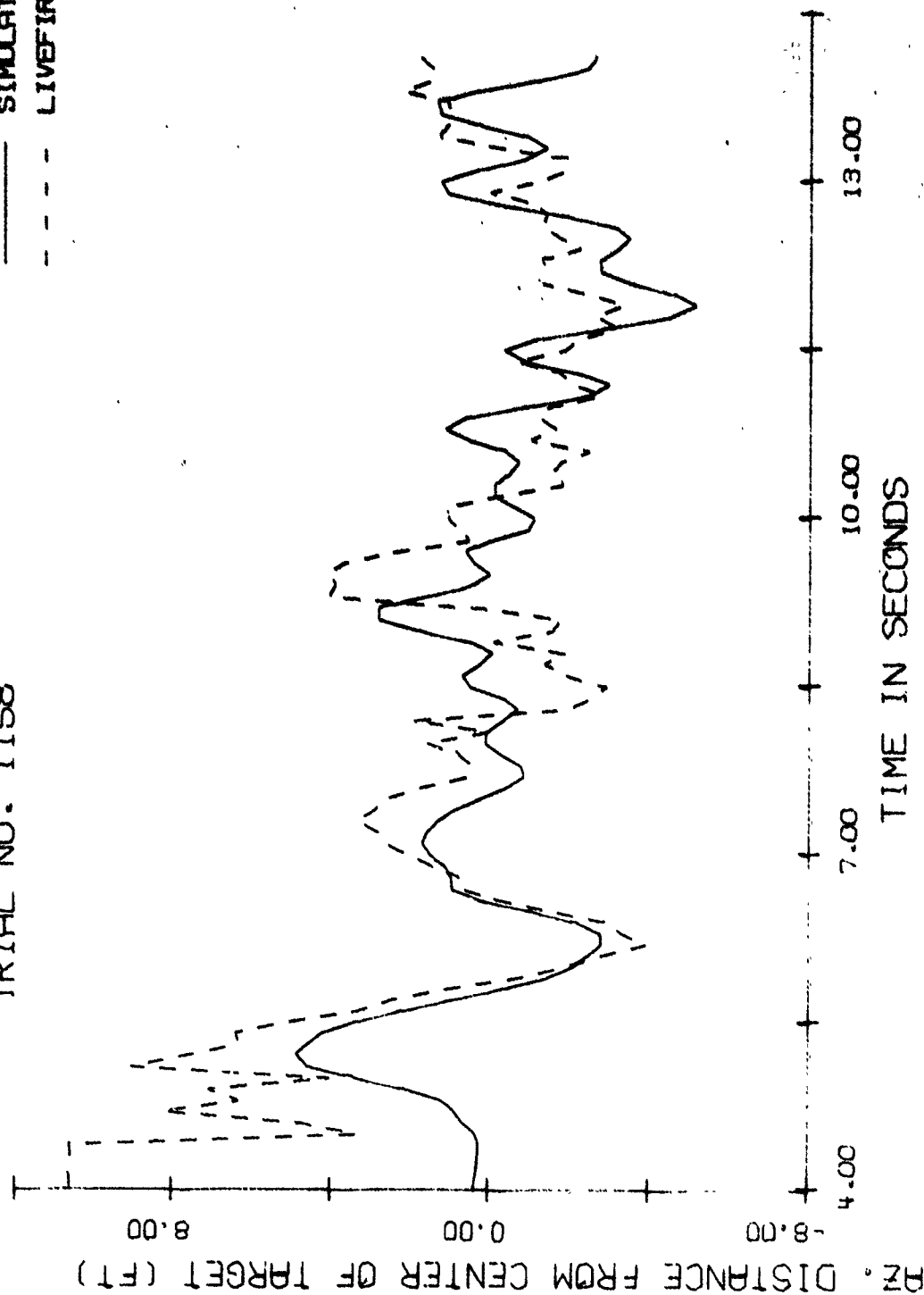
TARGET RANGE - 2855 METERS
TRIAL NO. 1158

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1158

— SIMULATION
--- LIVEFIRE

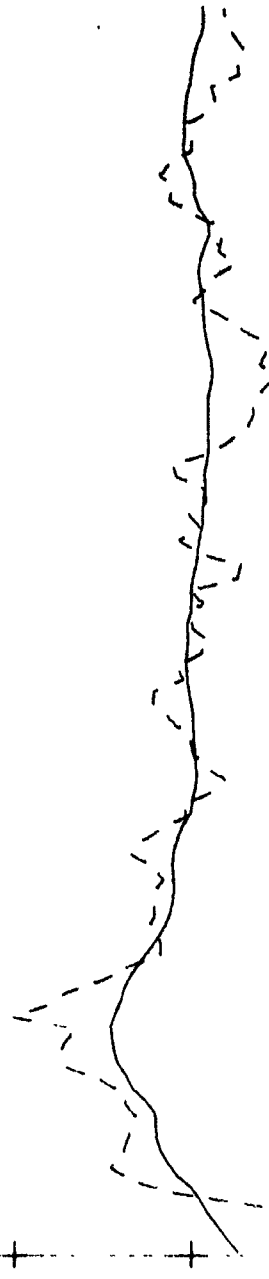


TARGET RANGE - 2855 METERS
 TRIAL NO. 1159

— SIMULATION
 - - - LIVEFIRE

FL. DISTANCE FROM CENTER OF TARGET (FT)

8.00
 0.00
 -8.00
 4.00

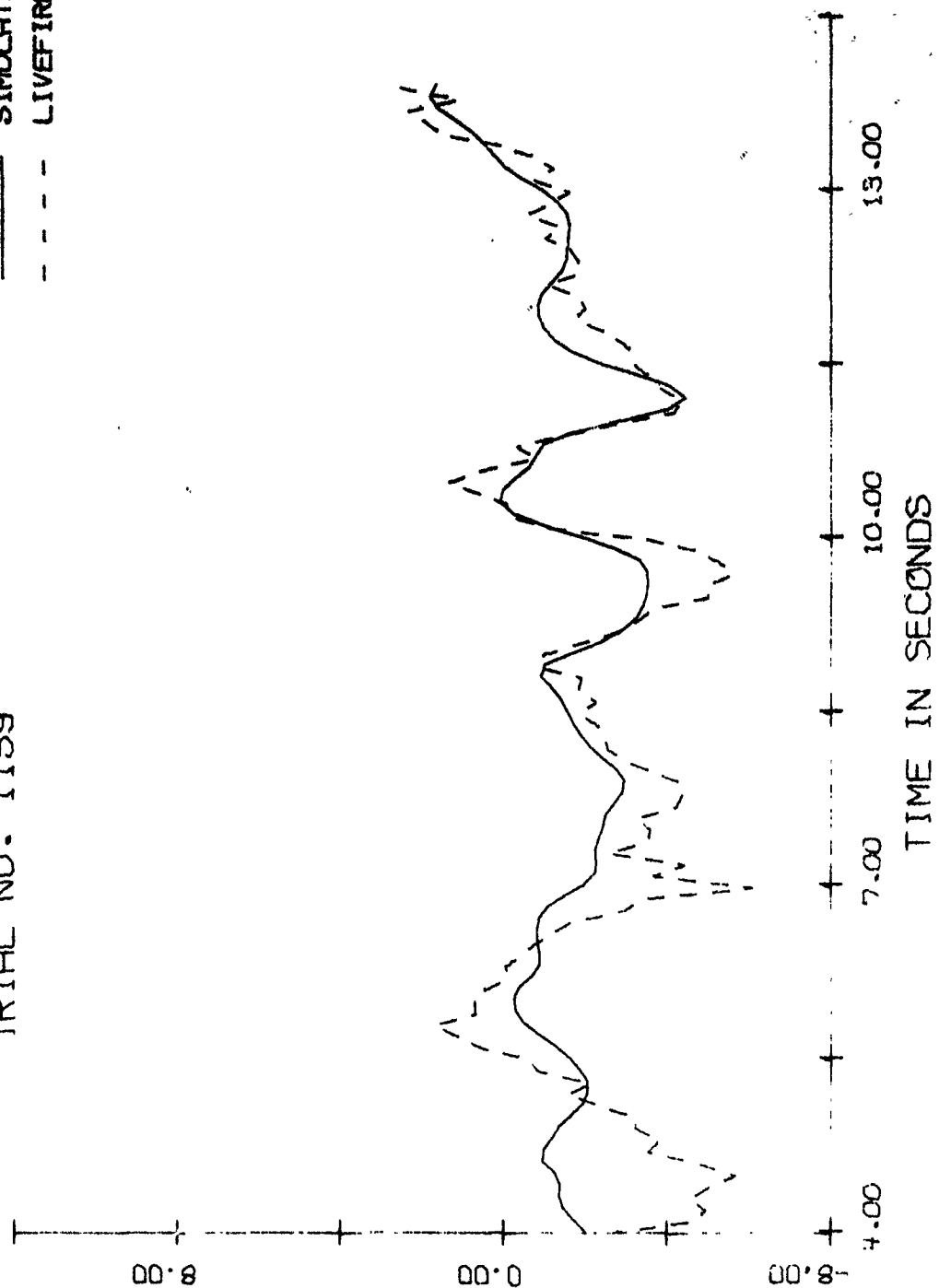


7.00
 10.00
 13.00
 TIME IN SECONDS

AZ, DISTANCE FROM CENTER OF TARGET (FT)

— SIMULATION
- - - LIVEFIRE

TARGET RANGE - 2855 METERS
TRIAL NO. 1159



TARGET RANGE - 2855 METERS
 TRIAL NO. 1201

— SIMULATION
 - - - LIVEFIRE

FL. DISTANCE FROM CENTER OF TARGET (FT)

13.00

10.00

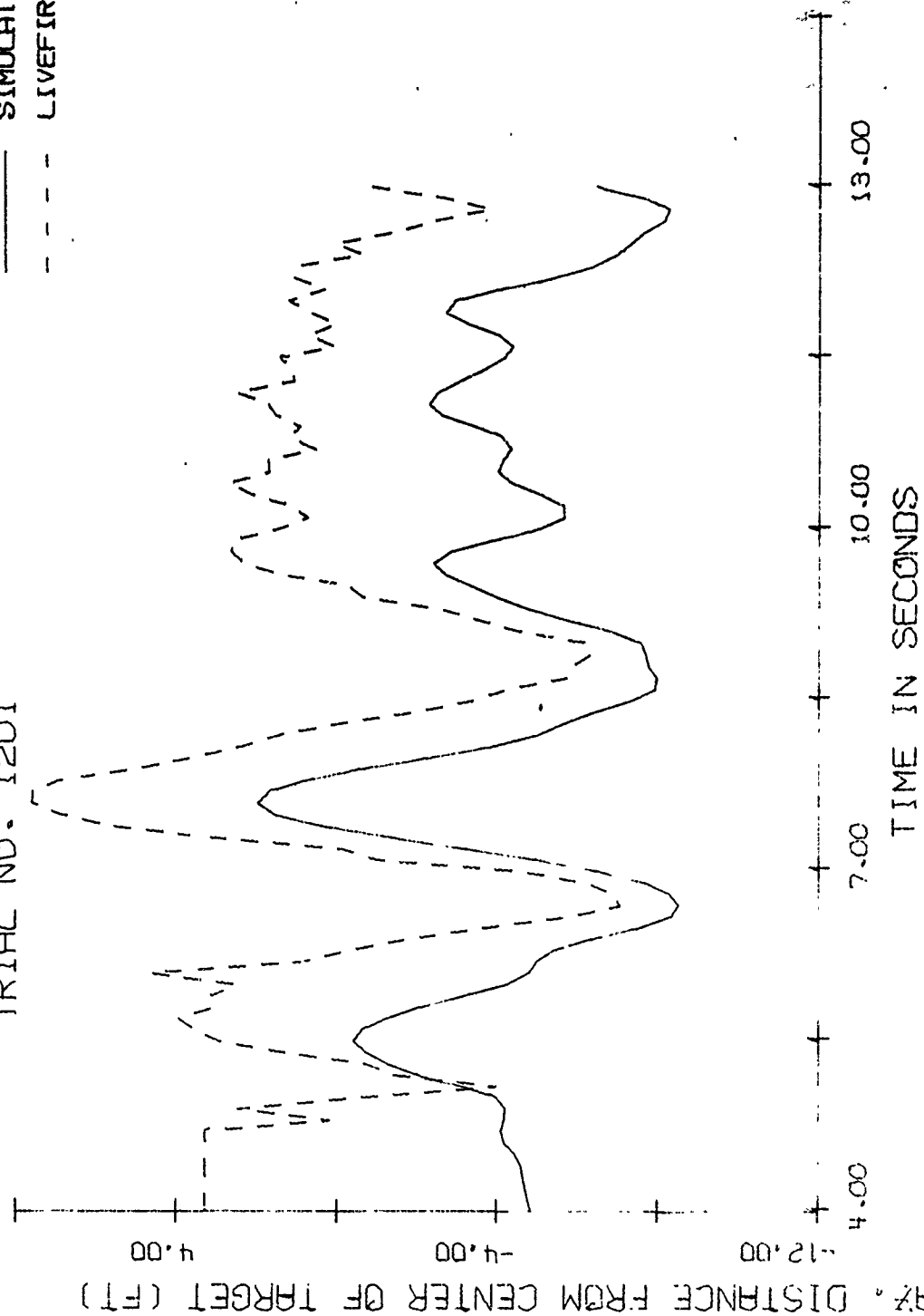
7.00

4.00

TIME IN SECONDS

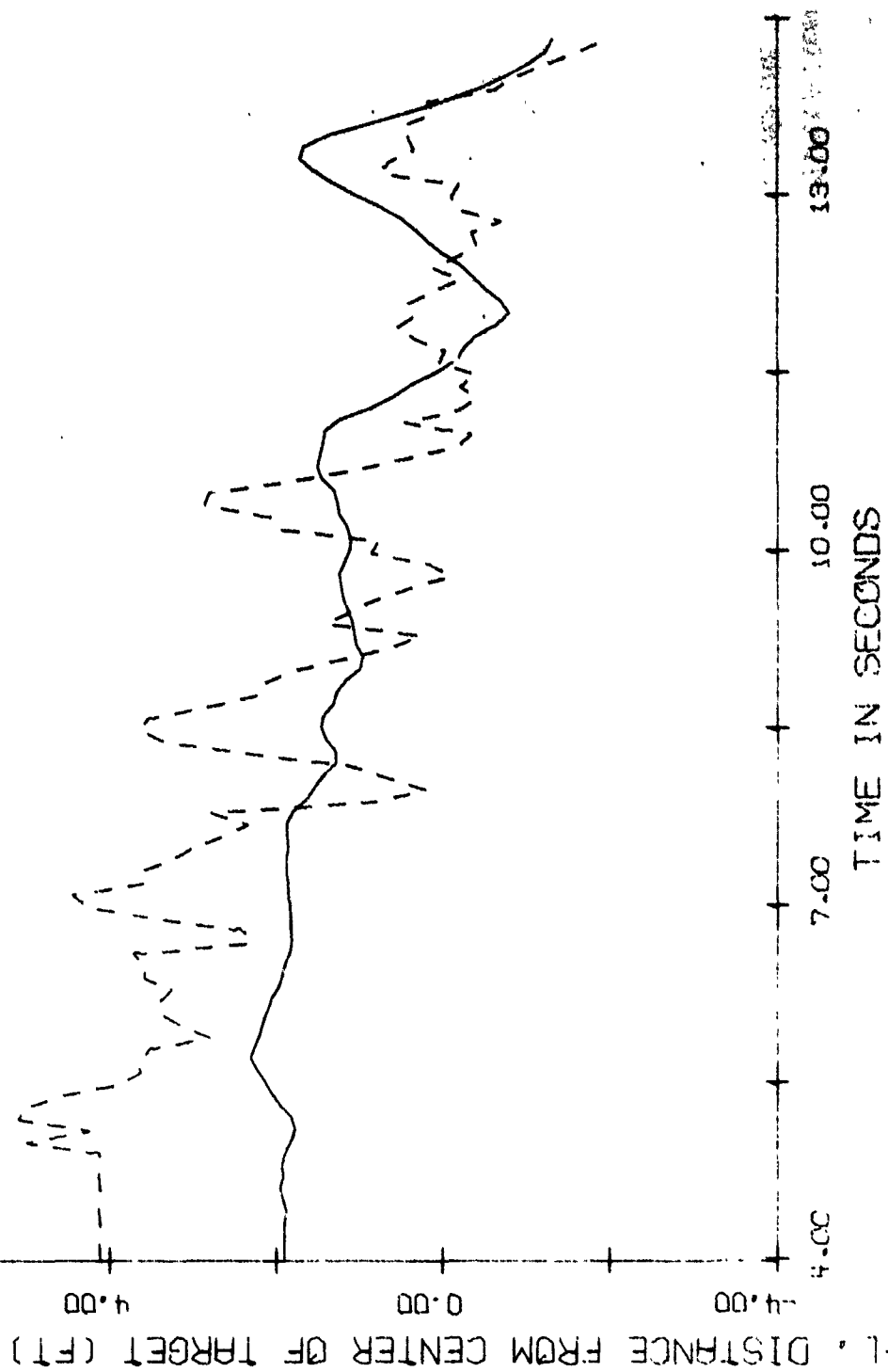
TARGET RANGE - 2855 METERS
TRIAL NO. 1201

— SIMULATION
- - - LIVEFIRE



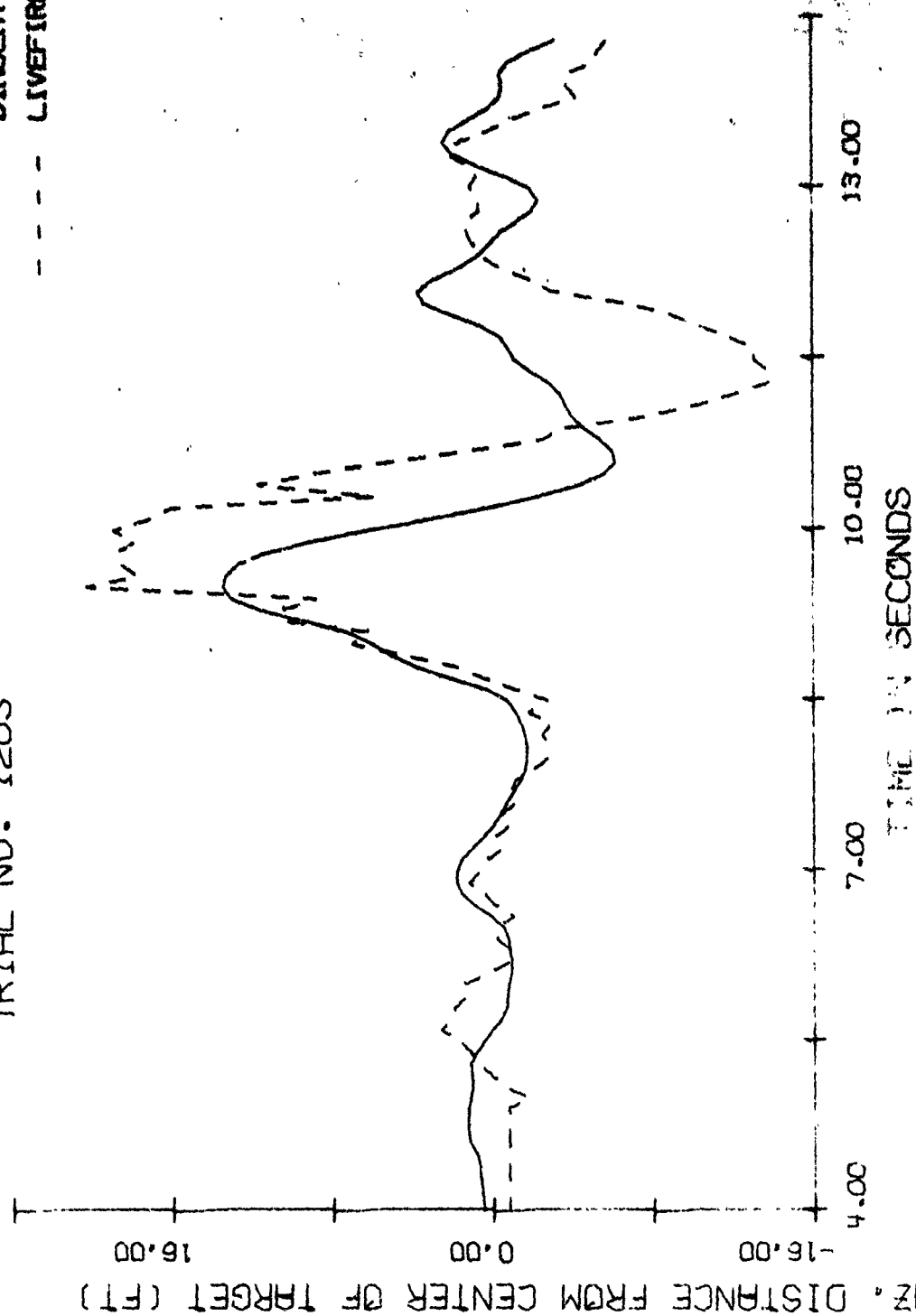
TARGET RANGE - 2855 METERS
 TRIAL NO. 1203

— SIMULATION
 --- LIVEFIRE

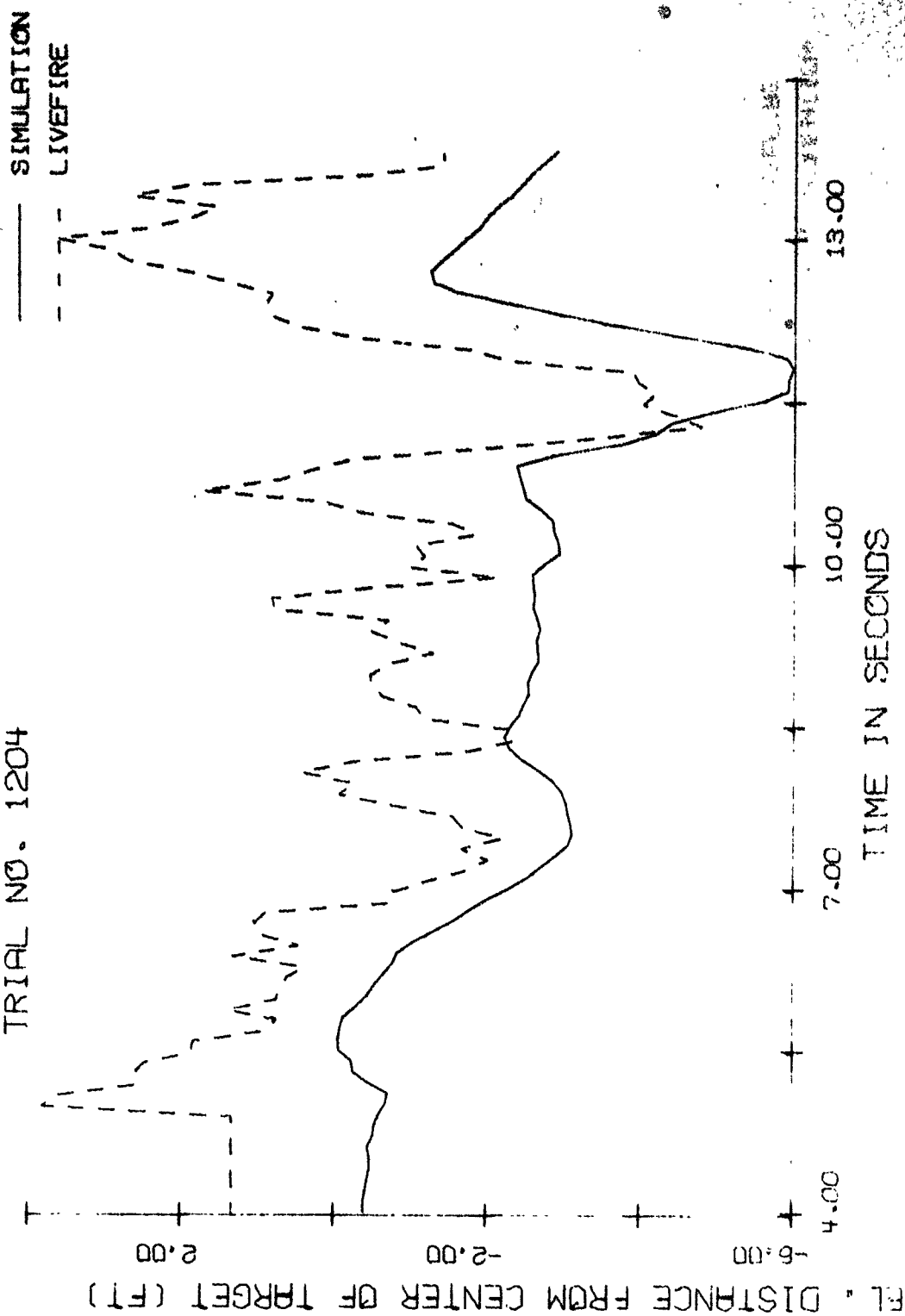


TARGET RANGE - 2855 METERS
TRIAL NO. 1203

— SIMULATION
- - - LIVEFIRE

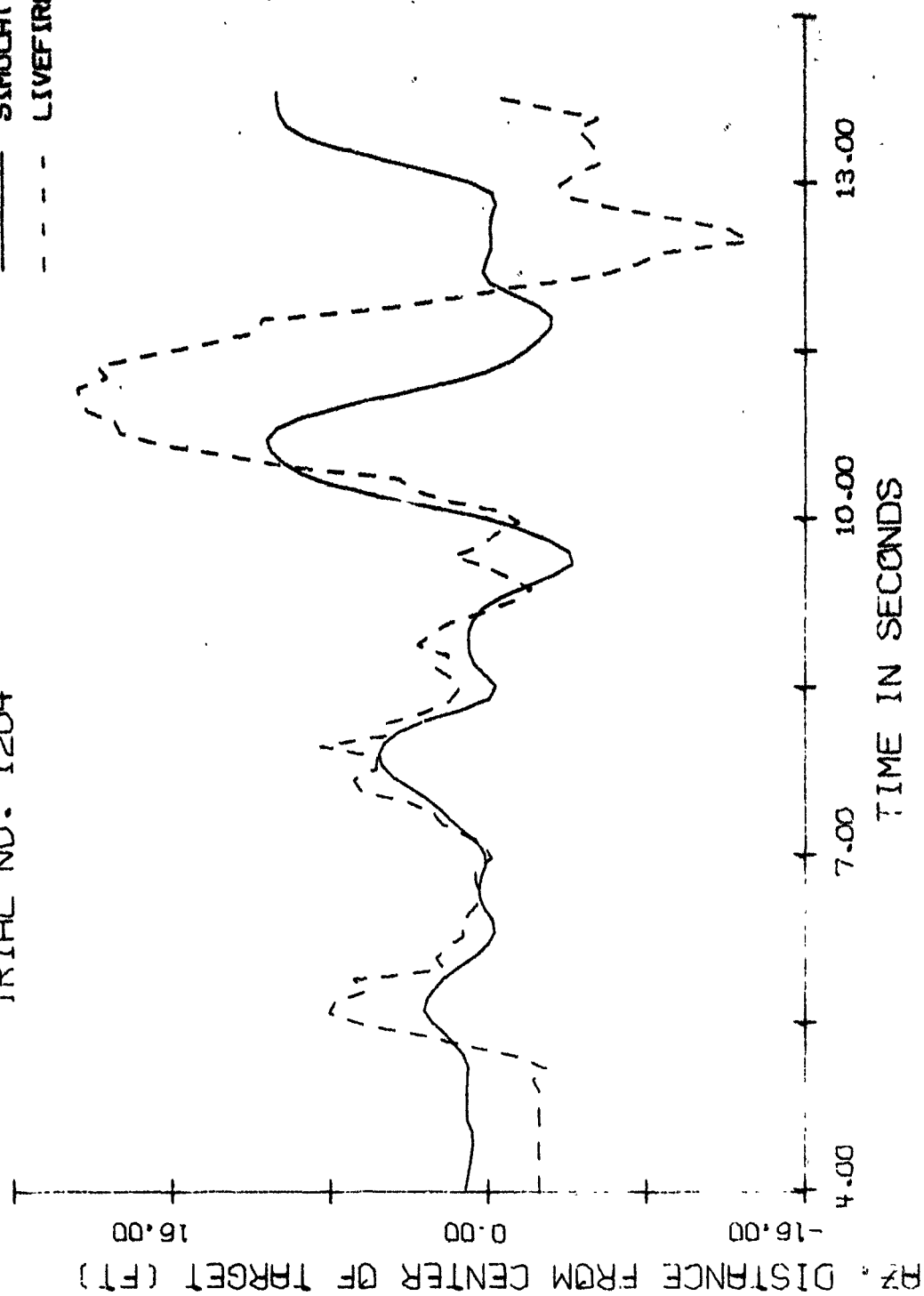


TARGET RANGE - 2855 METERS
TRIAL NO. 1204



TARGET RANGE - 2855 METERS
TRIAL NO. 1204

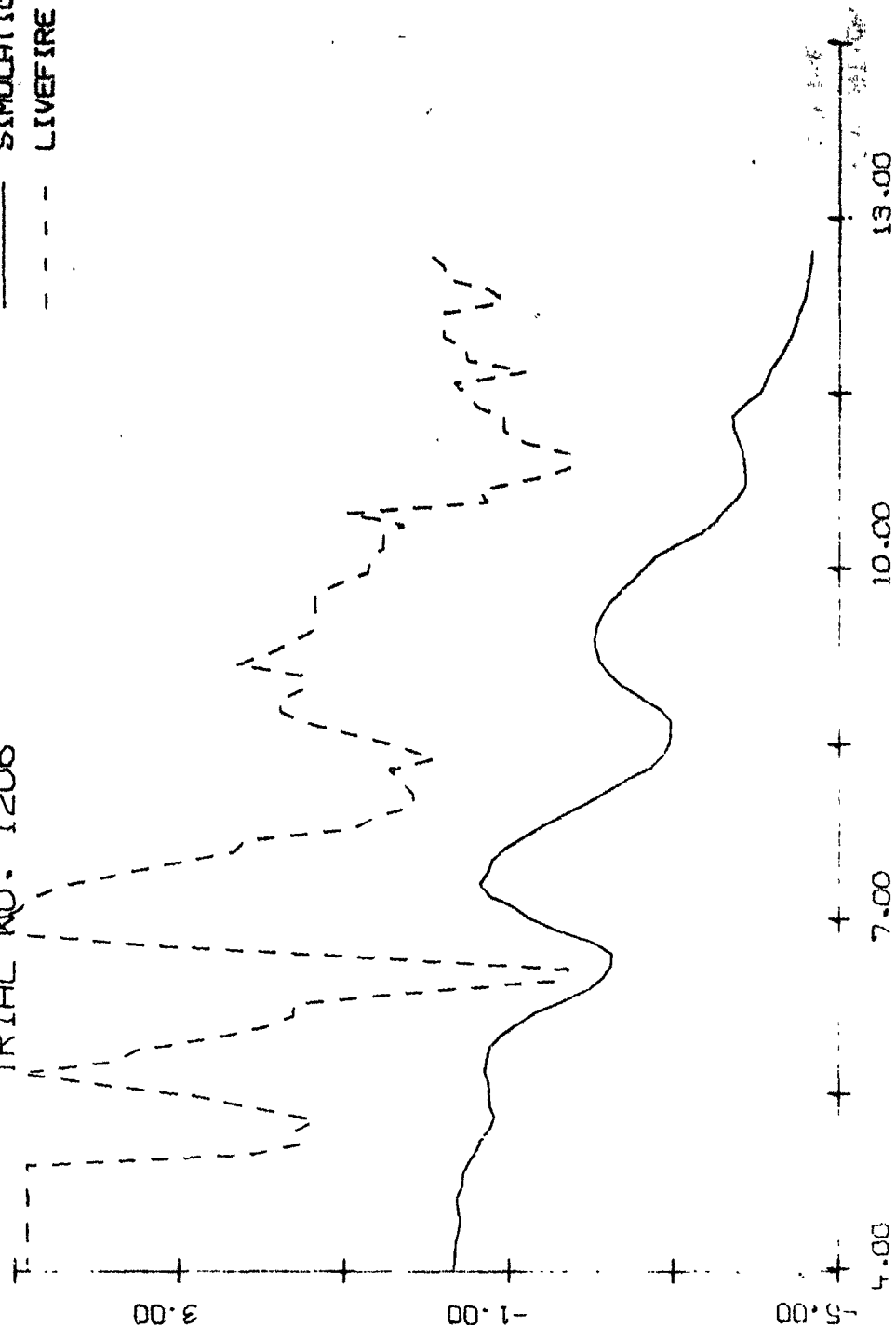
— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
 TRIAL NO. 1206

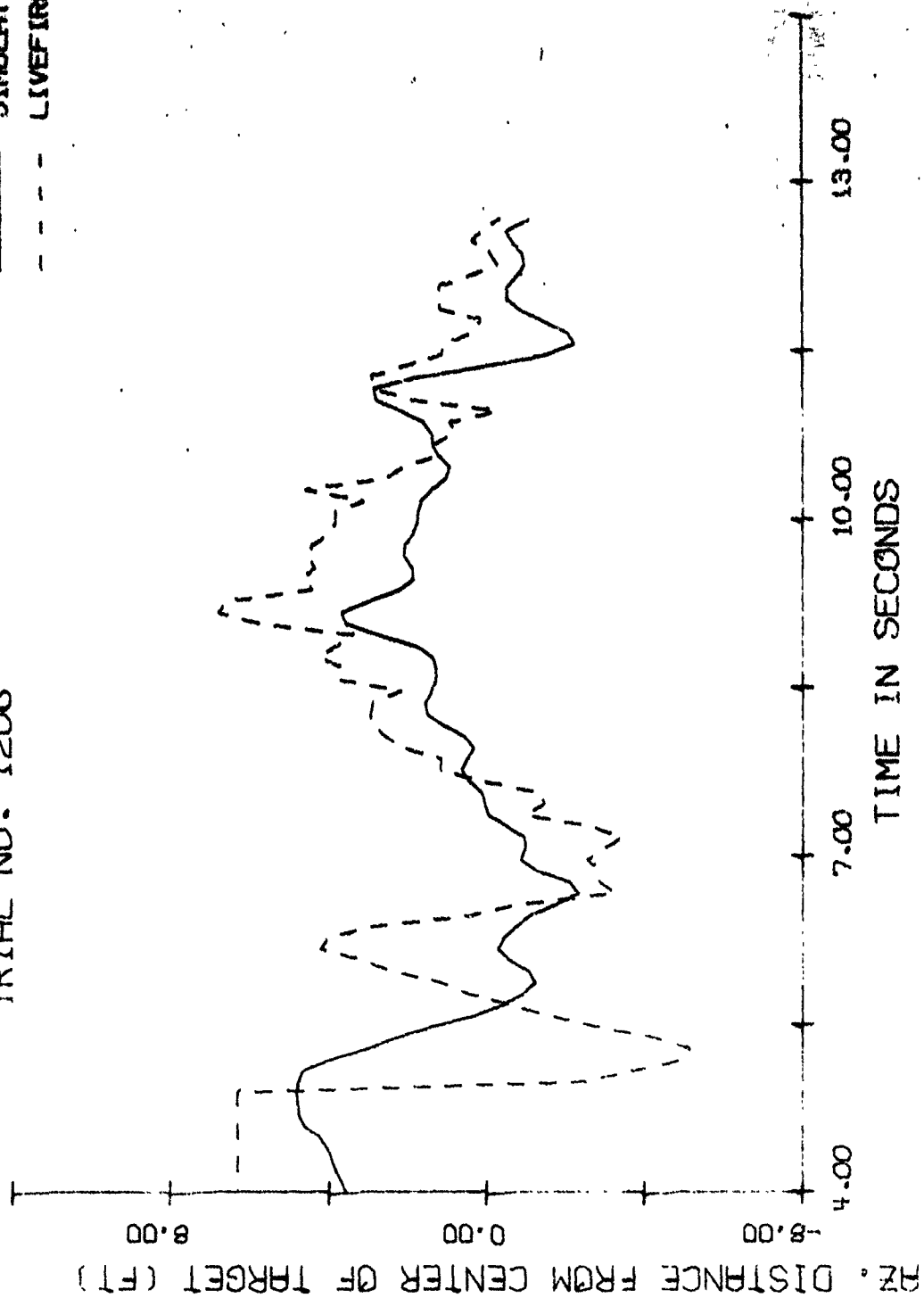
— SIMULATION
 --- LIVEFIRE

FL. DISTANCE FROM CENTER OF TARGET (FT)



TARGET RANGE - 2855 METERS
 TRIAL NO. 1206

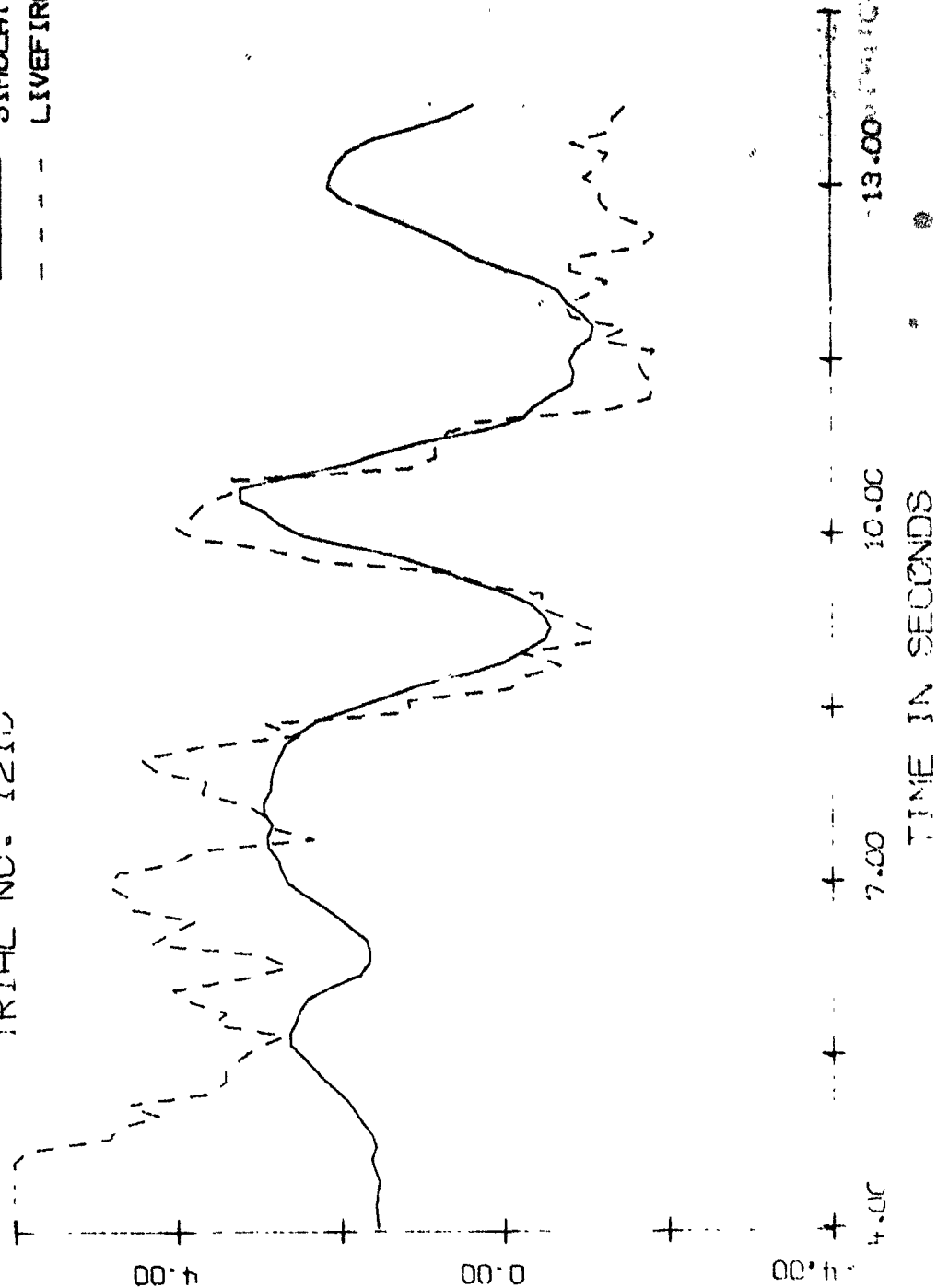
— SIMULATION
 --- LIVEFIRE



TARGET RANGE - 2855 METERS
 TRIAL NO. 1210

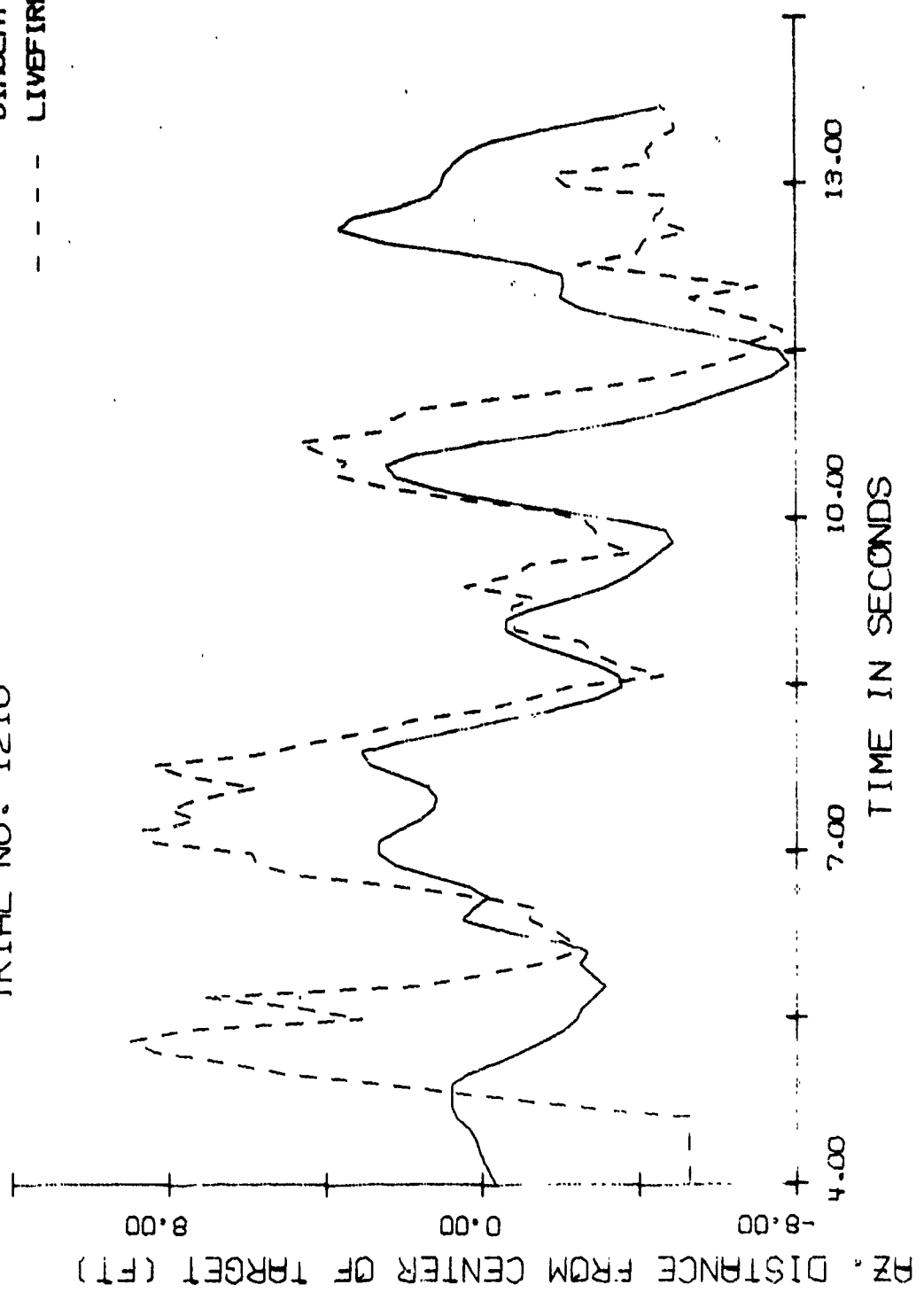
— SIMULATION
 - - - LIVEFIRE

1. DISTANCE FROM CENTER OF TARGET (FT)



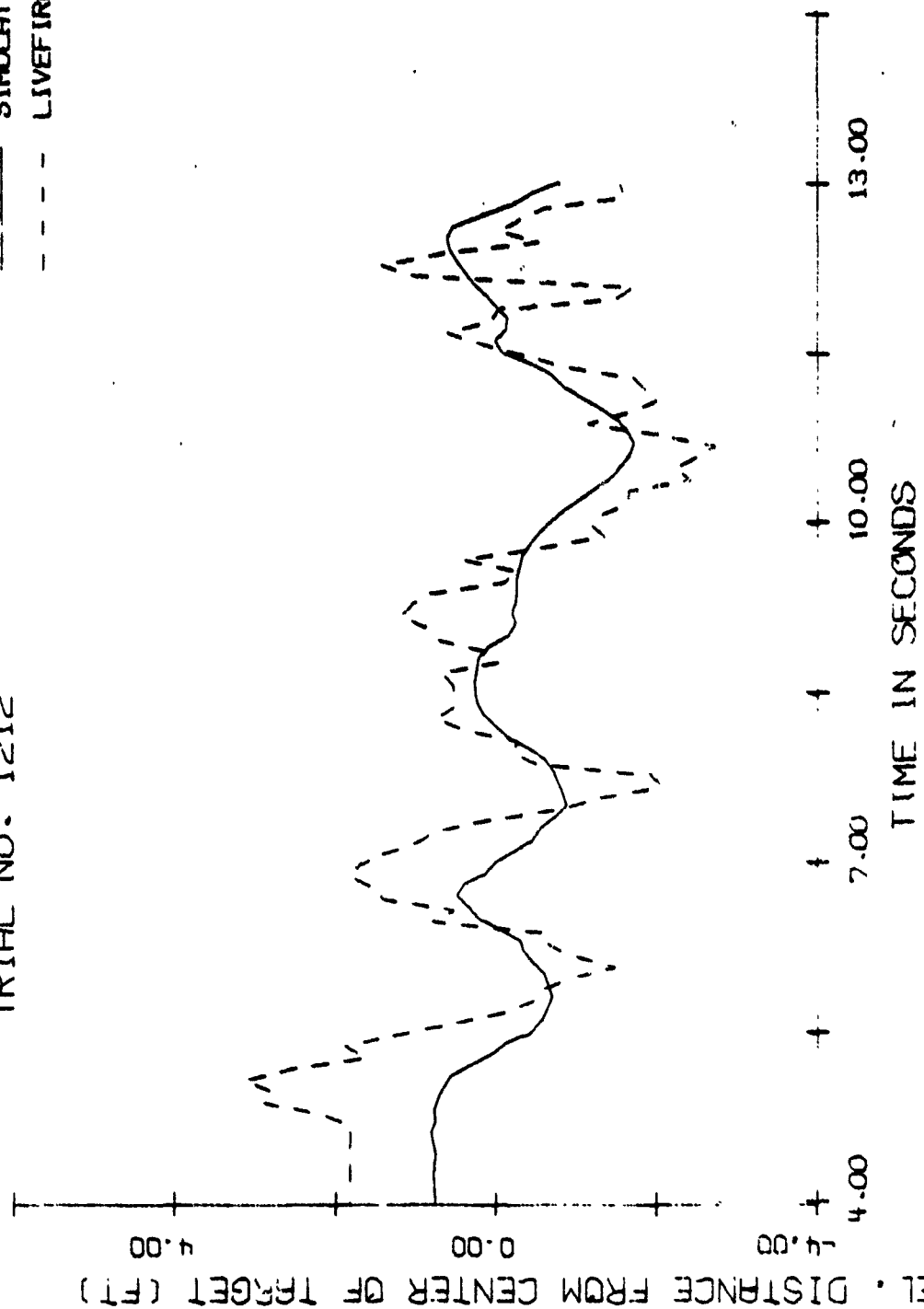
TARGET RANGE - 2855 METERS
TRIAL NO. 1210

— SIMULATION
- - - LIVEFIRE



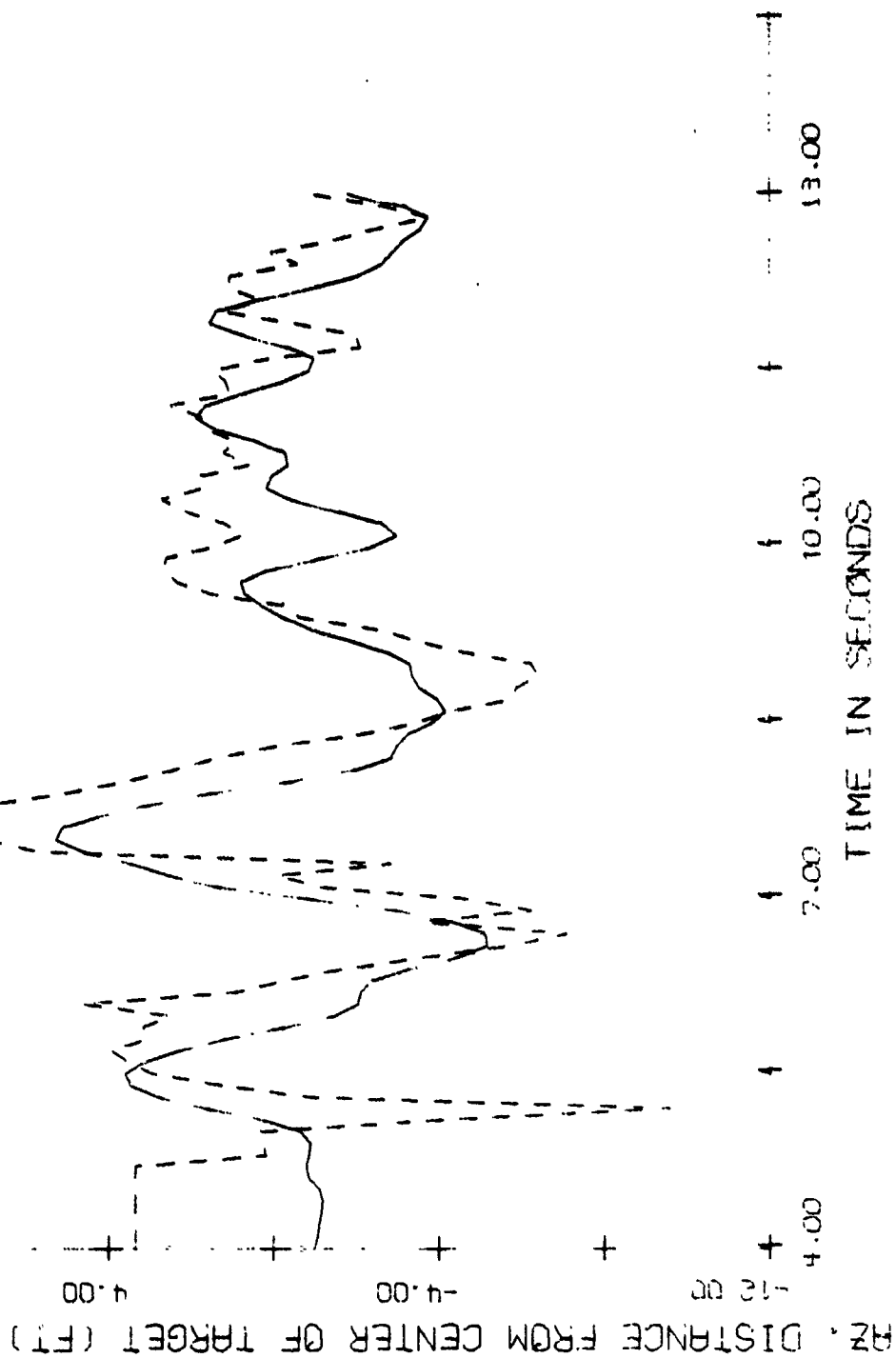
TARGET RANGE - 2855 METERS
 TRIAL NO. 1212

— SIMULATION
 - - - LIVEFIRE



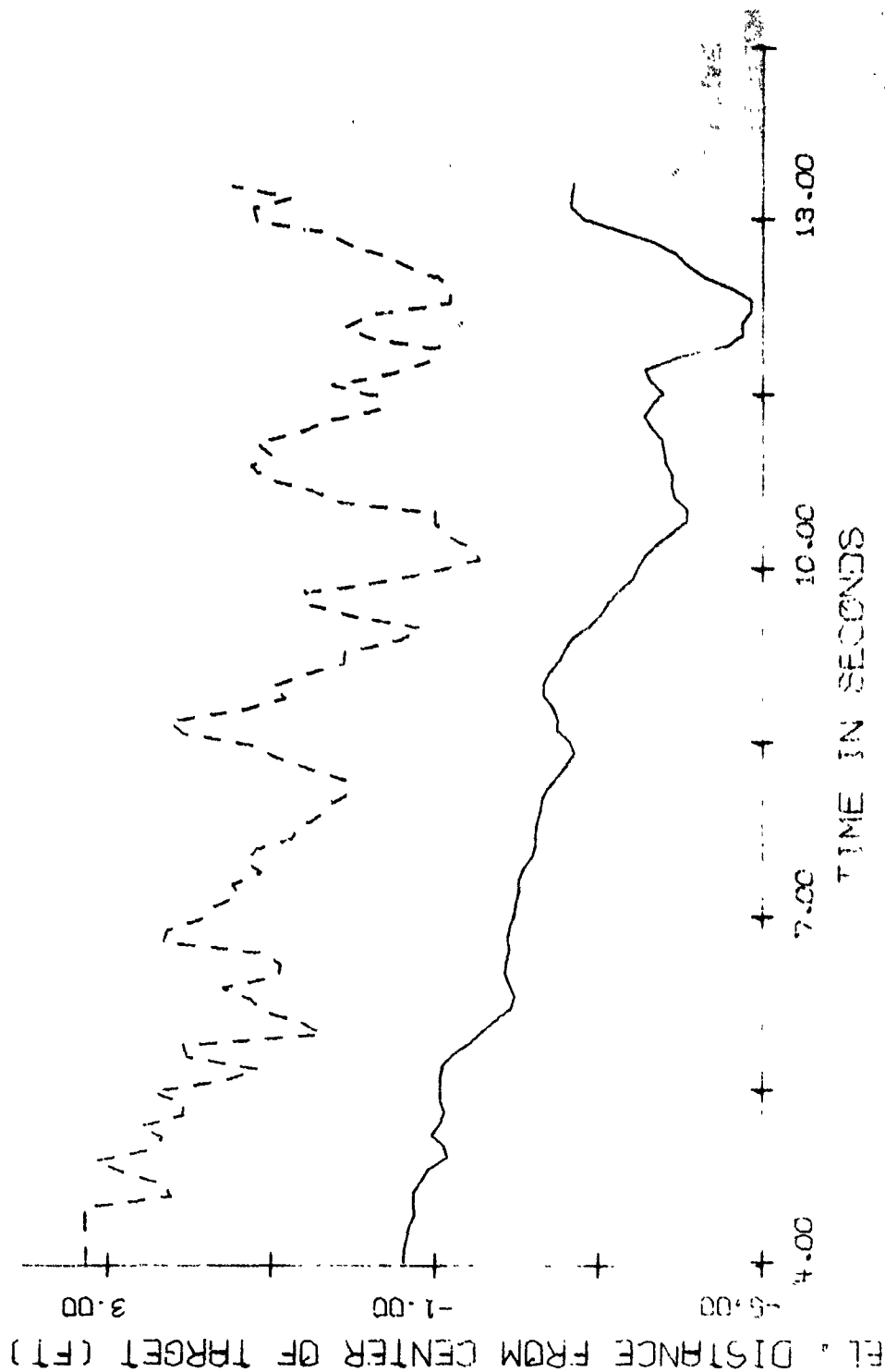
TARGET RANGE - 2855 METERS
 TRIAL NO. 1212

— SIMULATION
 --- LIVEFIRE



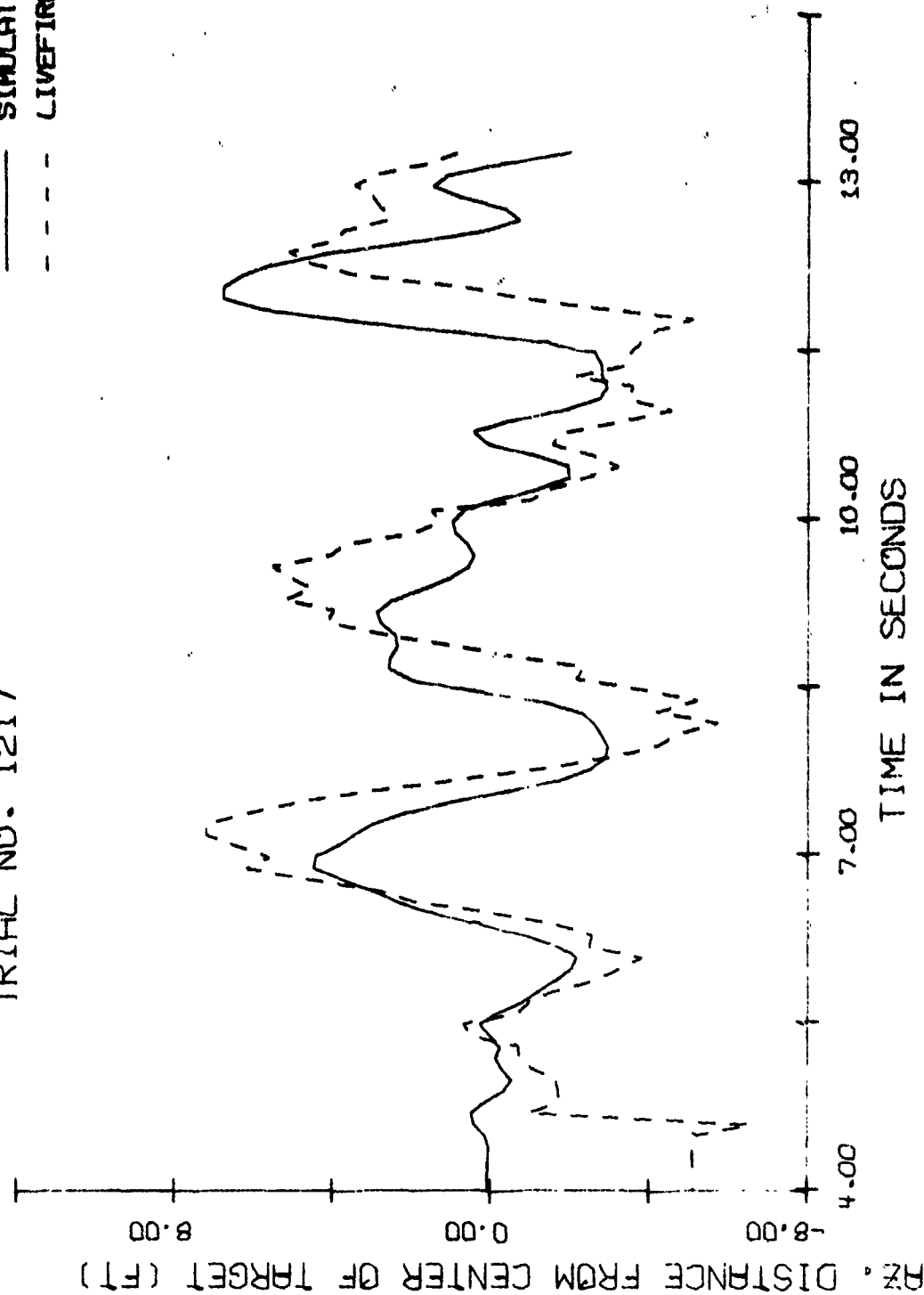
TARGET RANGE - 2855 METERS
TRIAL NO. 1217

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1217

— SIMULATION
-- LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1234

— SIMULATION
- - - LIVEFIRE

FL. DISTANCE FROM CENTER OF TARGET (FT)

8.00
0.00
-8.00

4.00

7.00

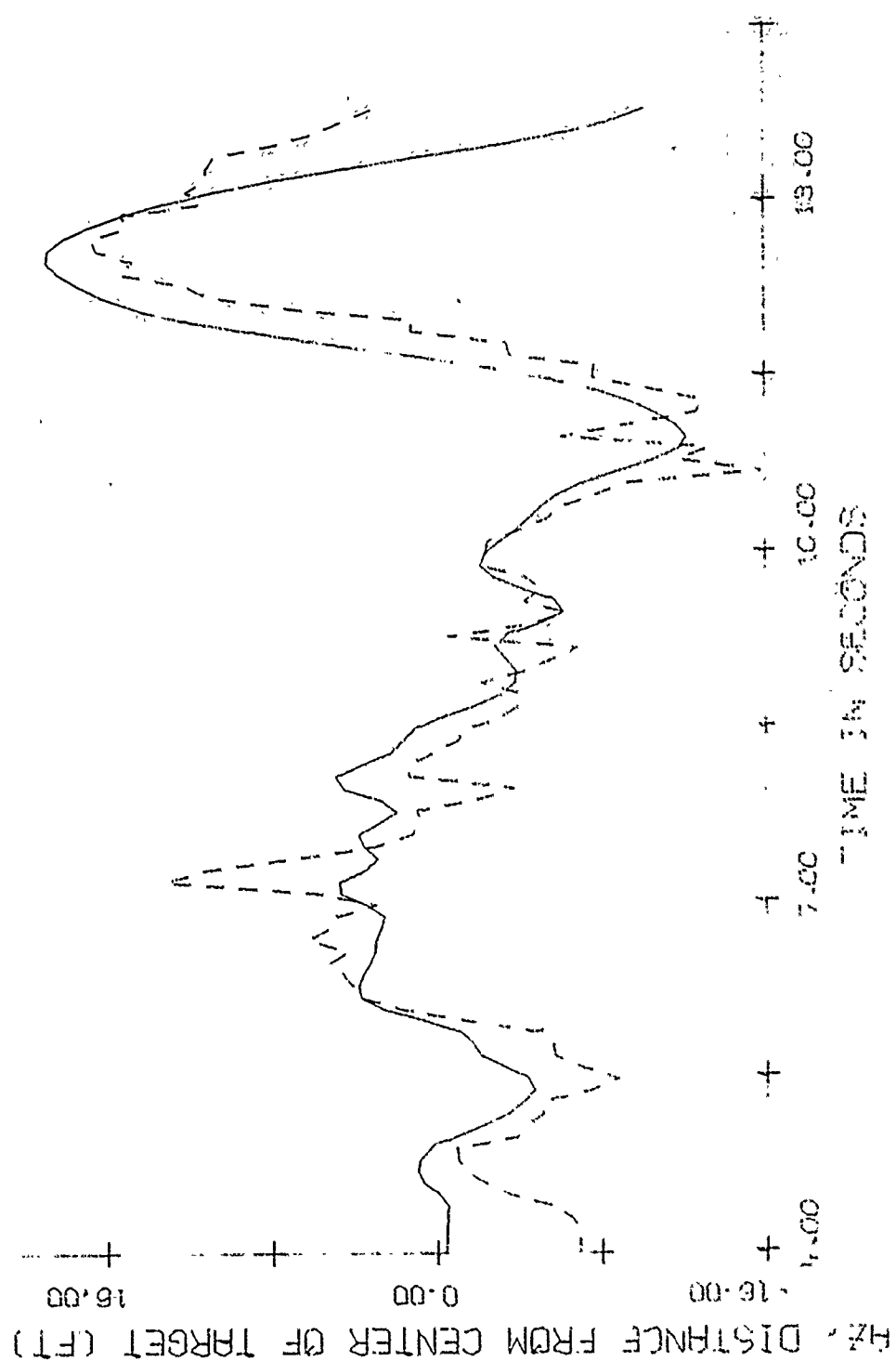
10.00

13.00

TIME IN SECONDS

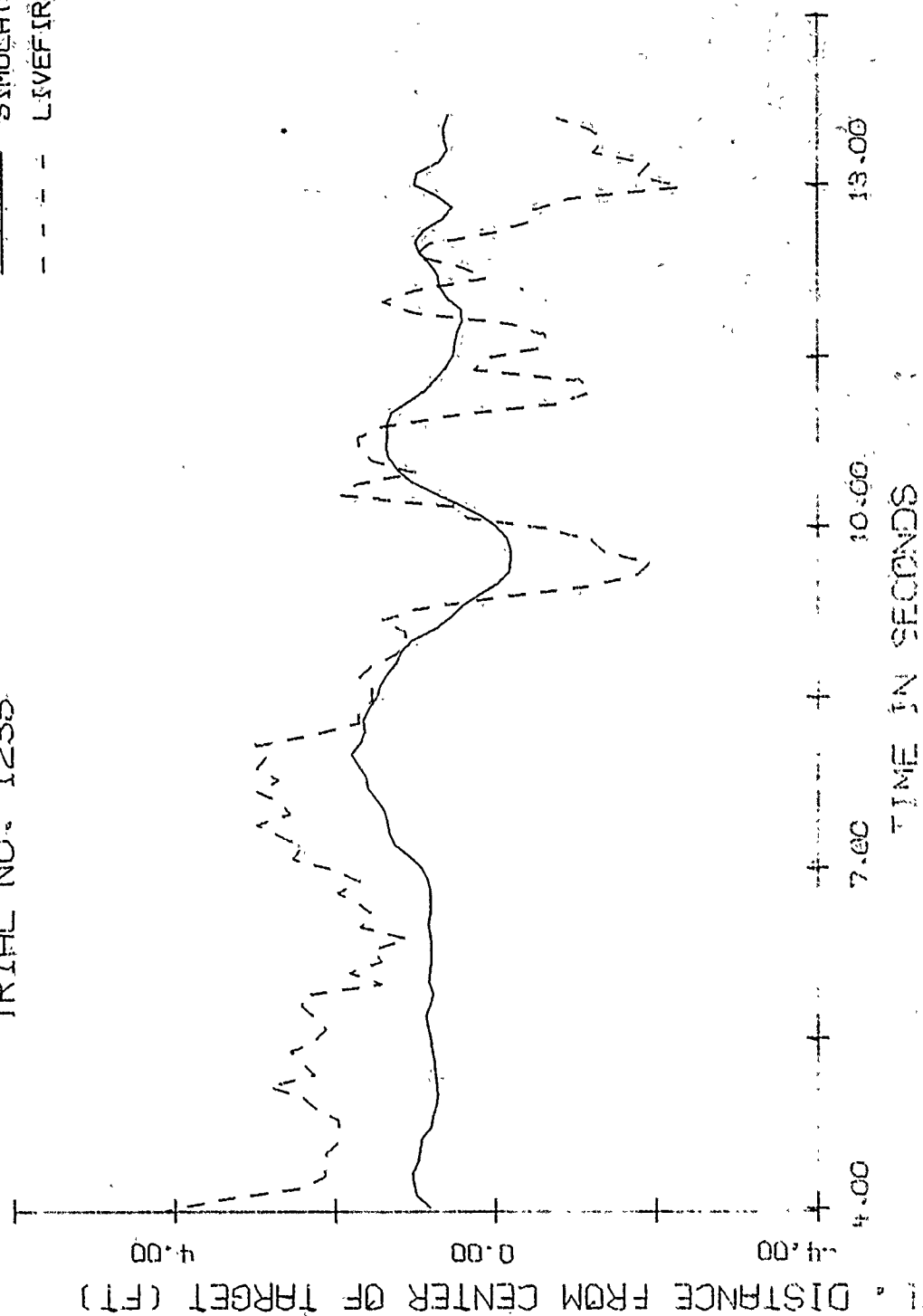
TARGET RANGE - 2355 METERS
 TRIAL NO. 1234

— SIMULATION
 - - - LIVEFIRE



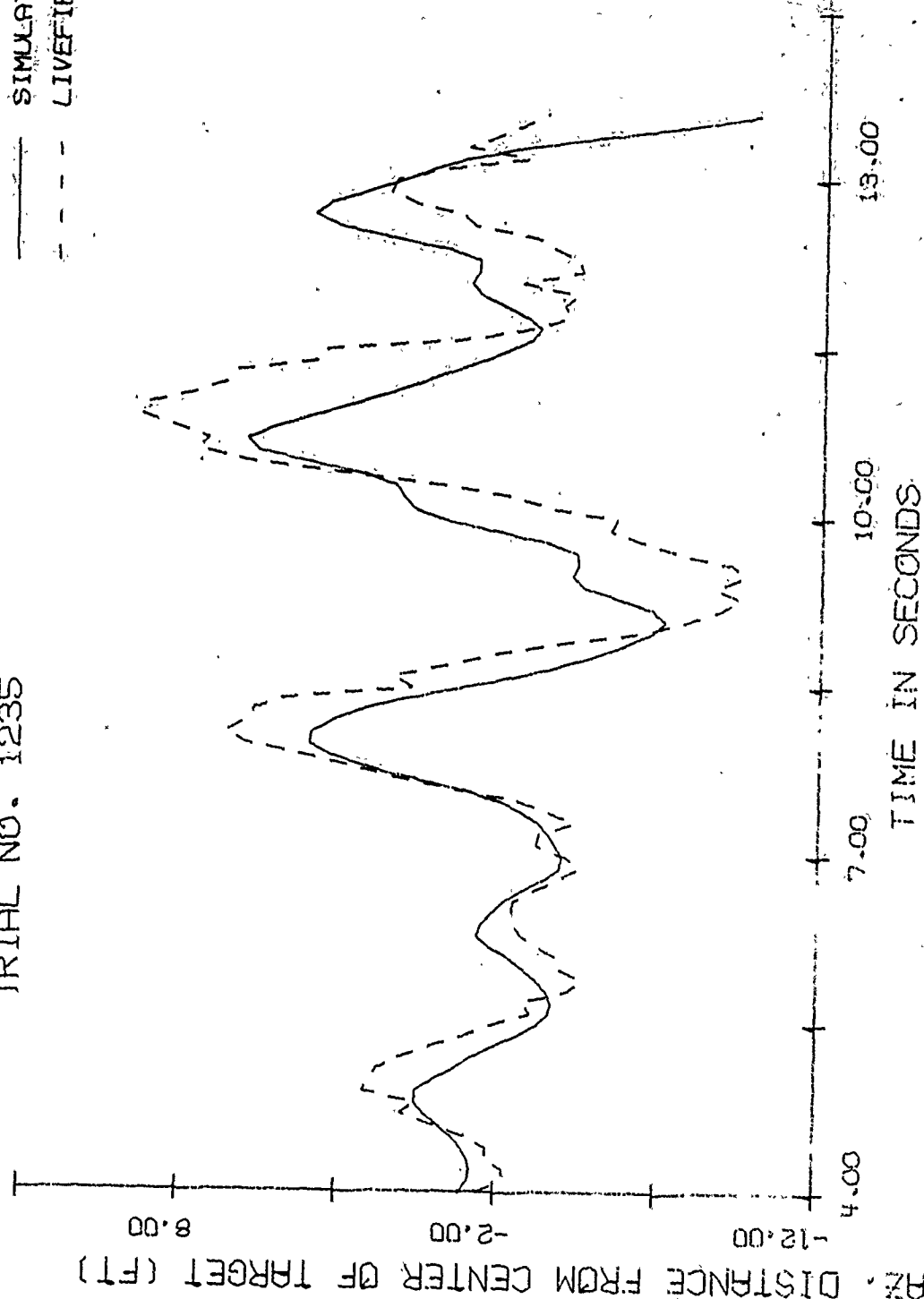
TARGET RANGE - 2855 METERS
 TRIAL NO. 1235

— SIMULATION
 - - - LIVEFIRE



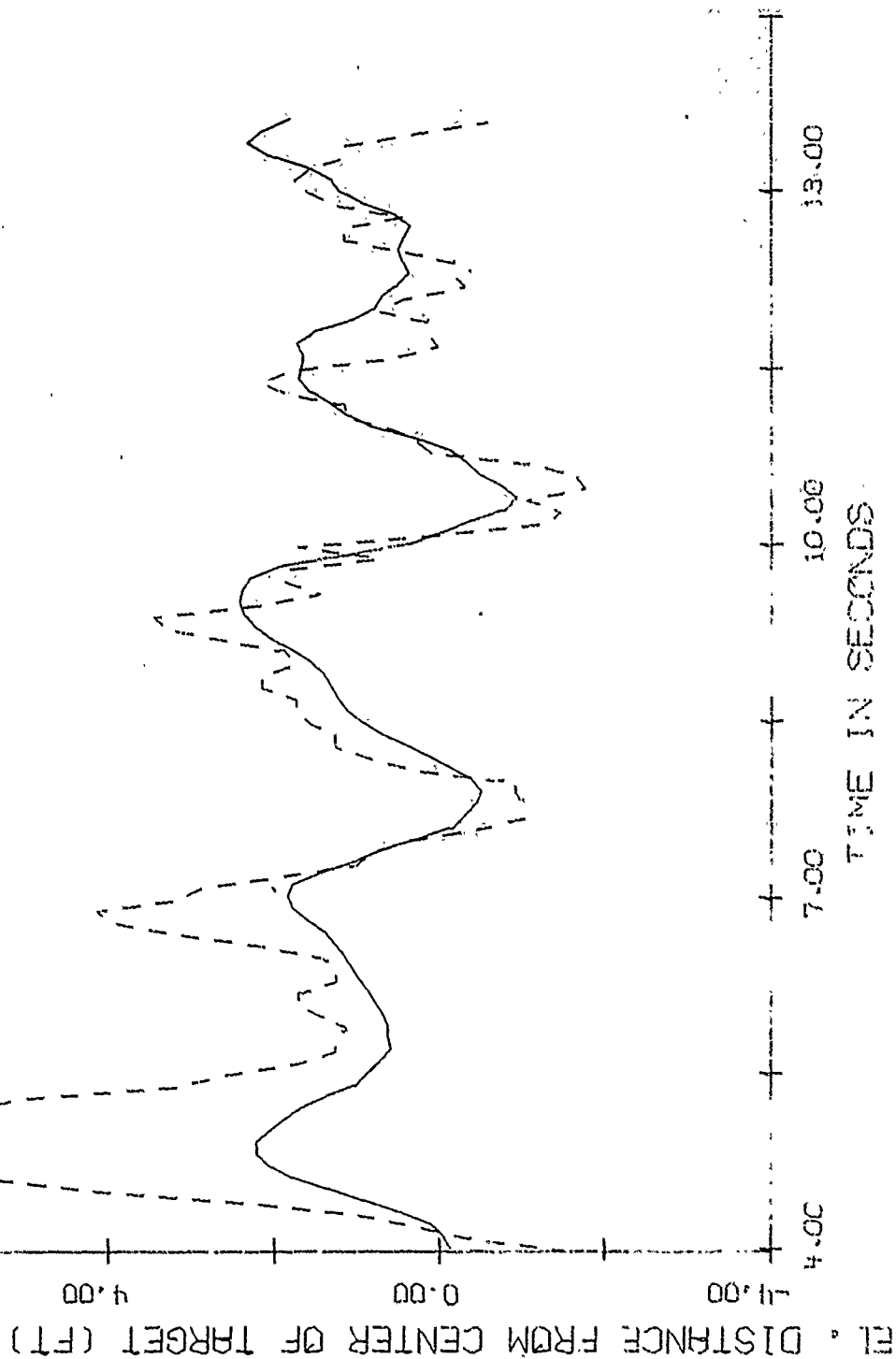
TARGET RANGE - 2855 METERS
TRIAL NO. 1235

— SIMULATION
- - - LIVEFIRE



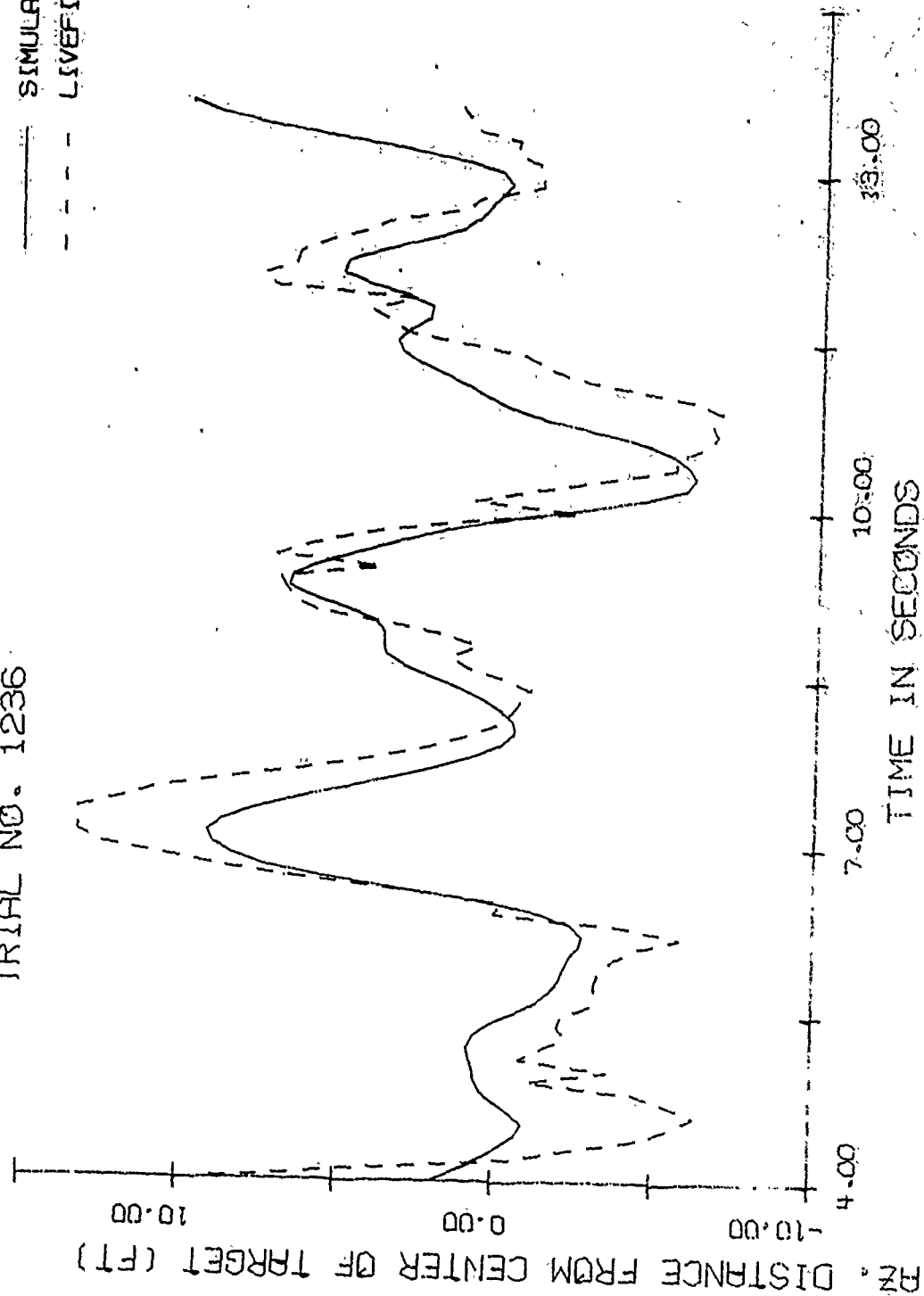
TARGET RANGE - 2855 METERS
TRIAL NO. 1236

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1236

— SIMULATION
- - - LIVEFIRE

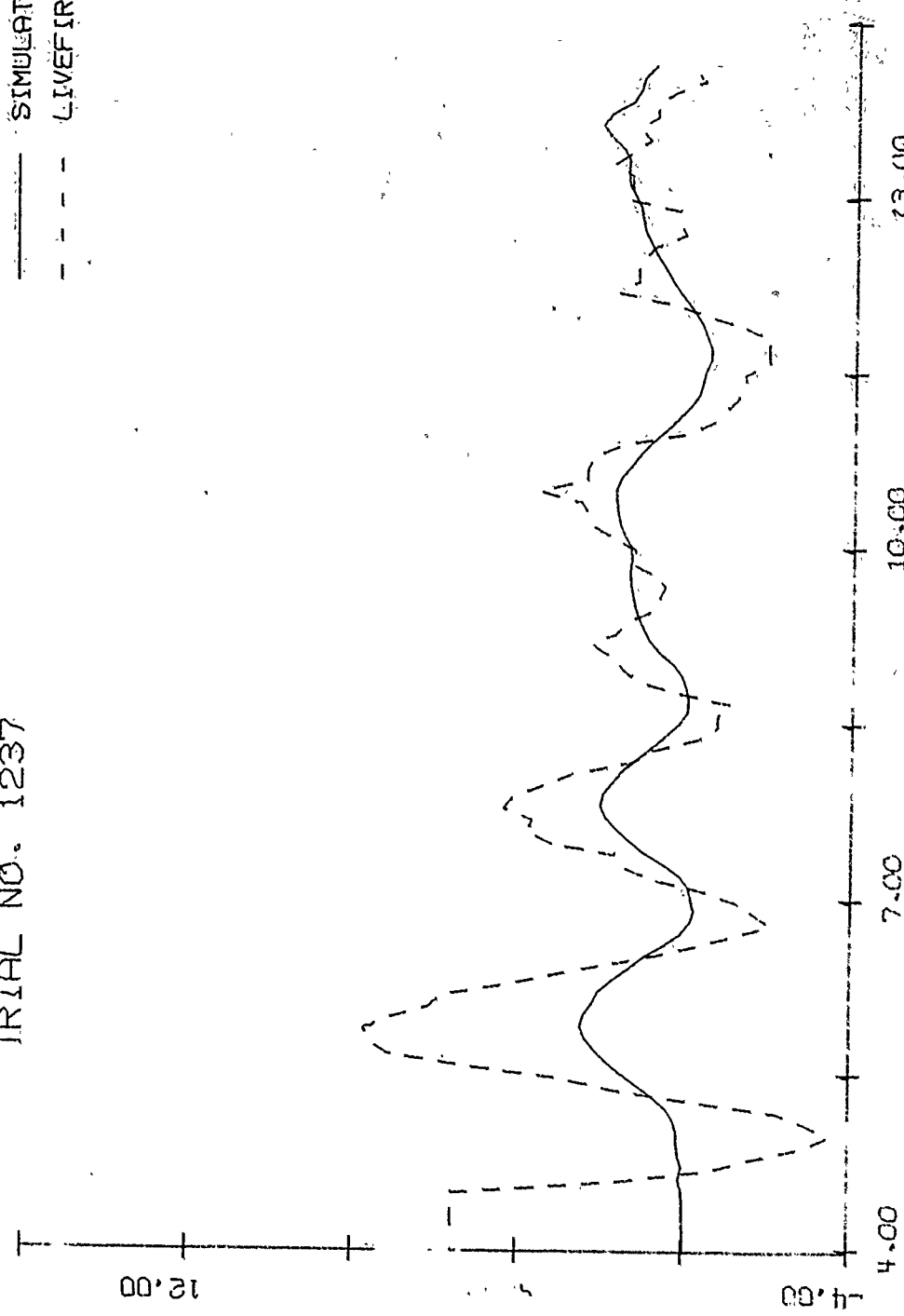


TARGET RANGE - 2855 METERS
 TRIAL NO. 1237

— SIMULATION
 - - - LIVEFIRE

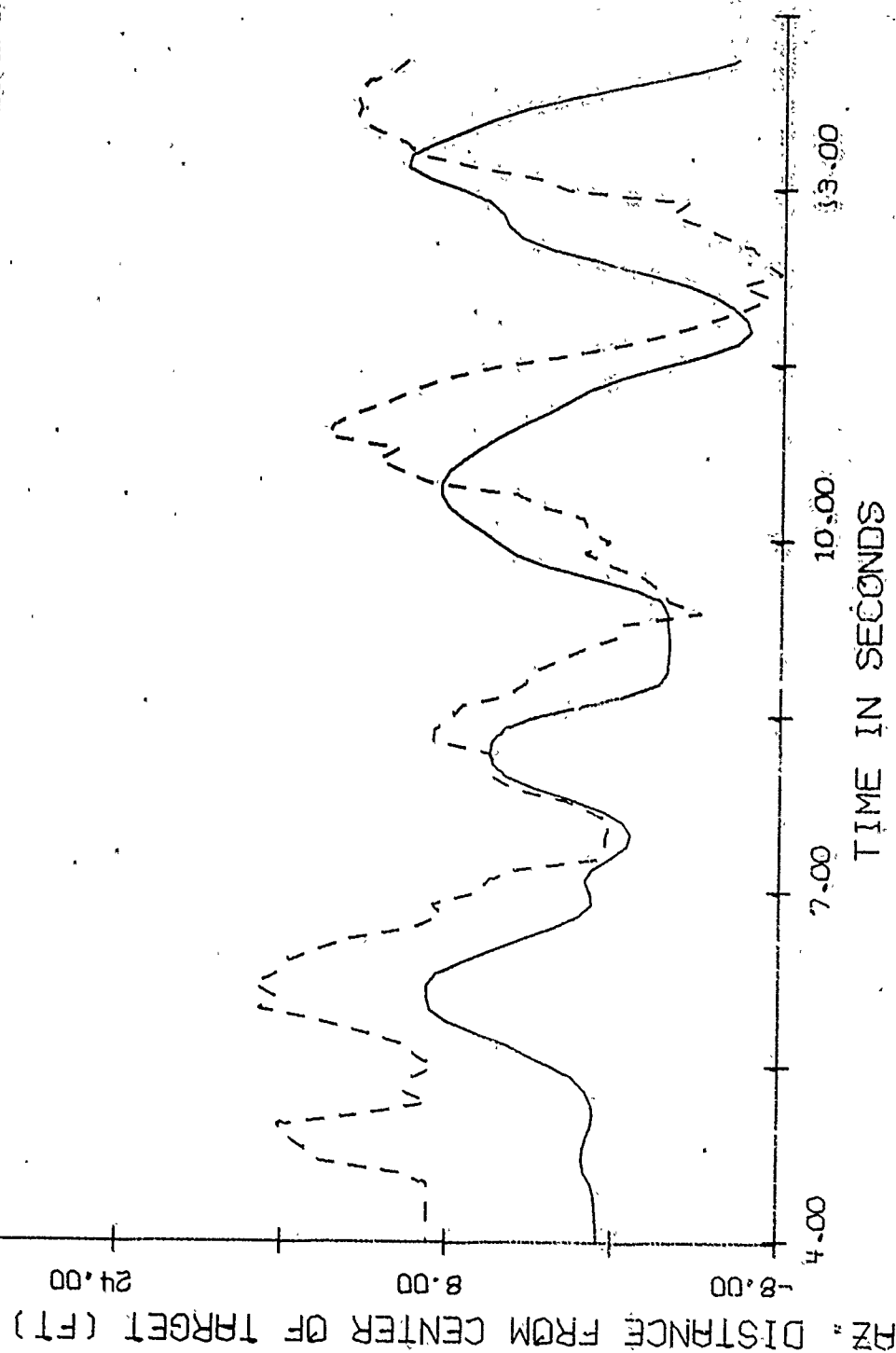
EL. DISTANCE FROM CENTER OF TARGET (FT)

TIME IN SECONDS



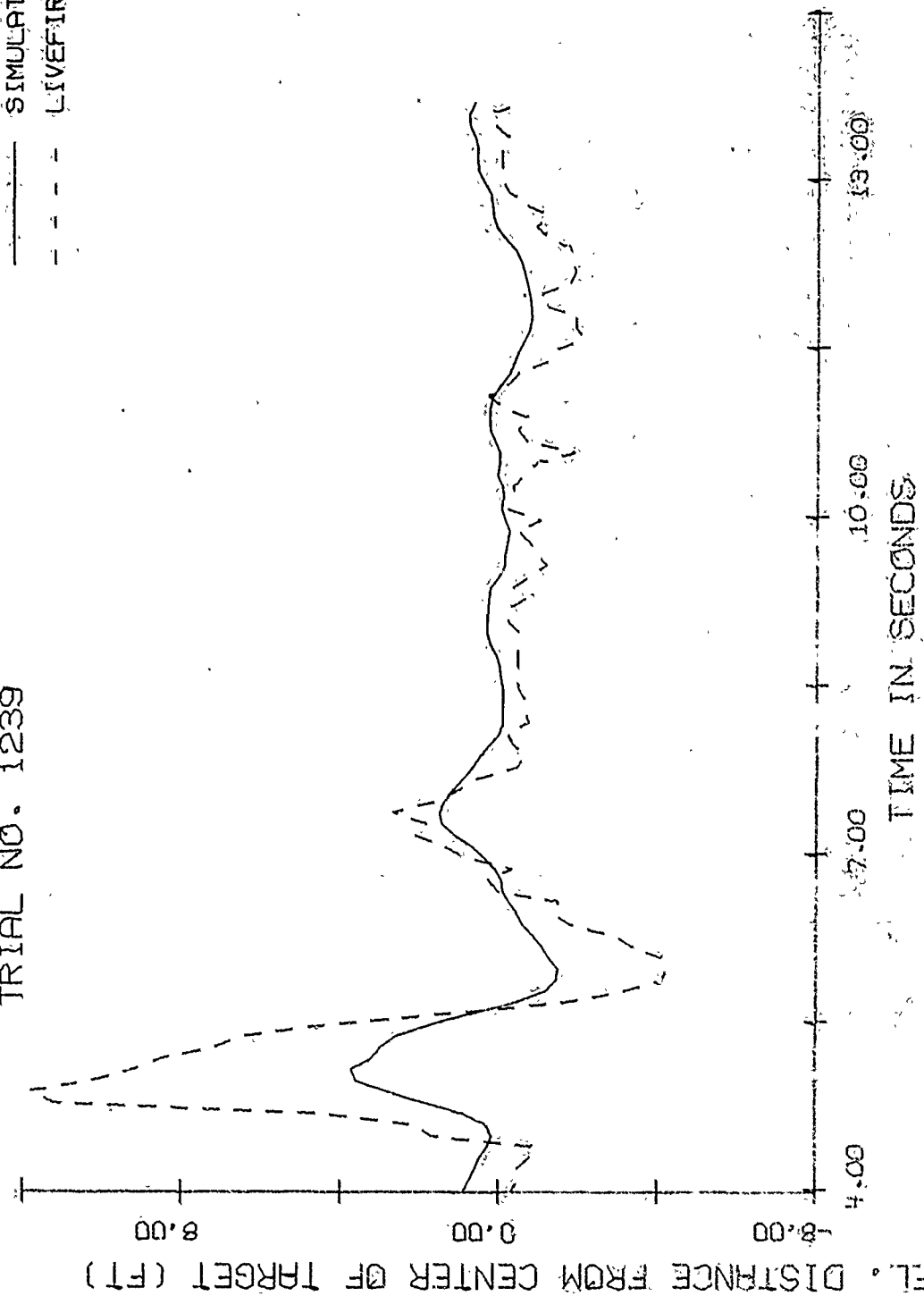
TARGET RANGE - 2855 METERS
TRIAL NO. 1237

— SIMULATION
- - - LIVEFIRE



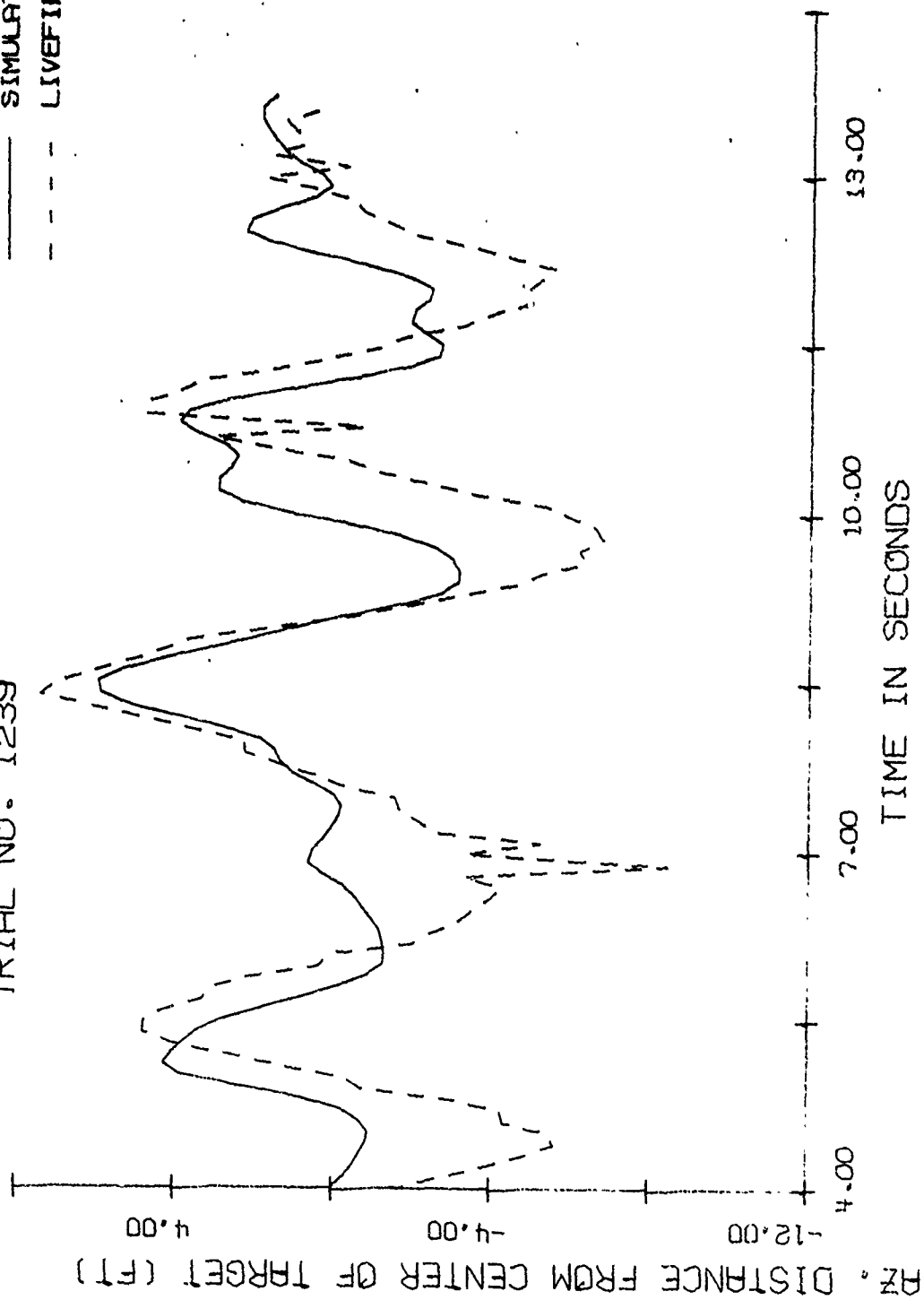
TARGET RANGE - 2855 METERS
 TRIAL NO. 1239

— SIMULATION
 - - - LIVEFIRE



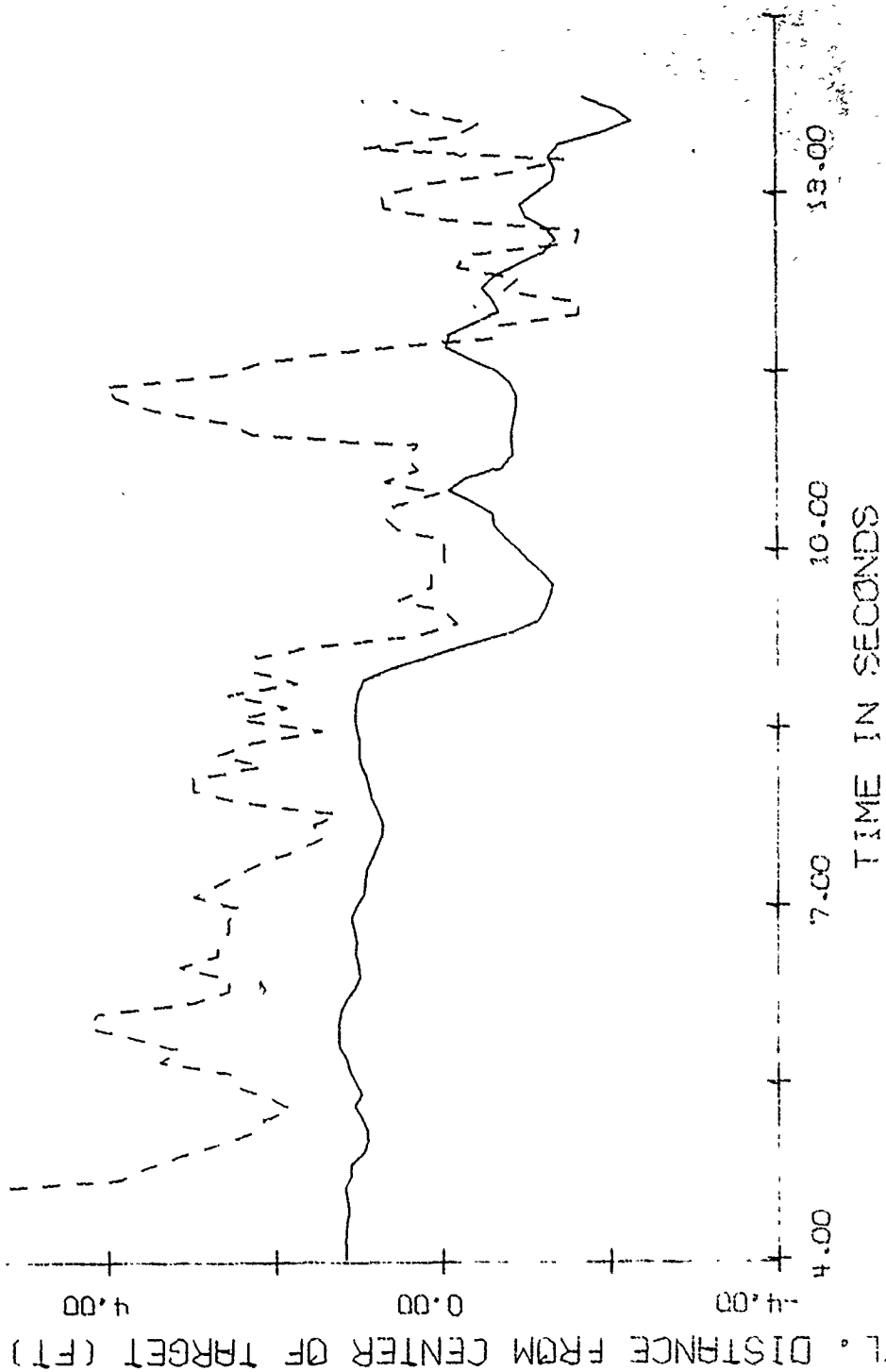
TARGET RANGE - 2855 METERS
TRIAL NO. 1239

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
 TRIAL NO. 1240

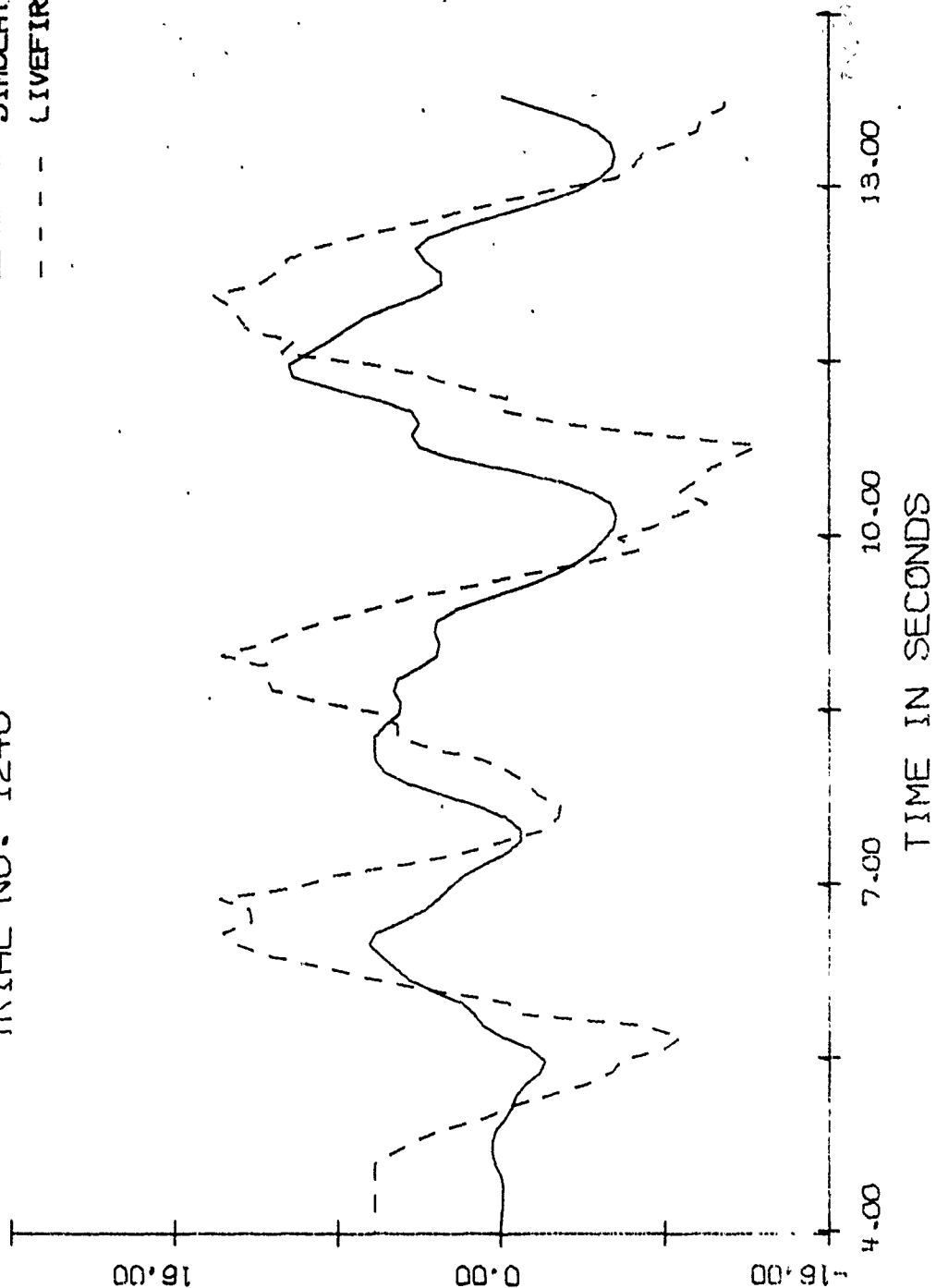
— SIMULATION
 --- LIVEFIRE



FE. DISTANCE FROM CENTER OF TARGET (FT)

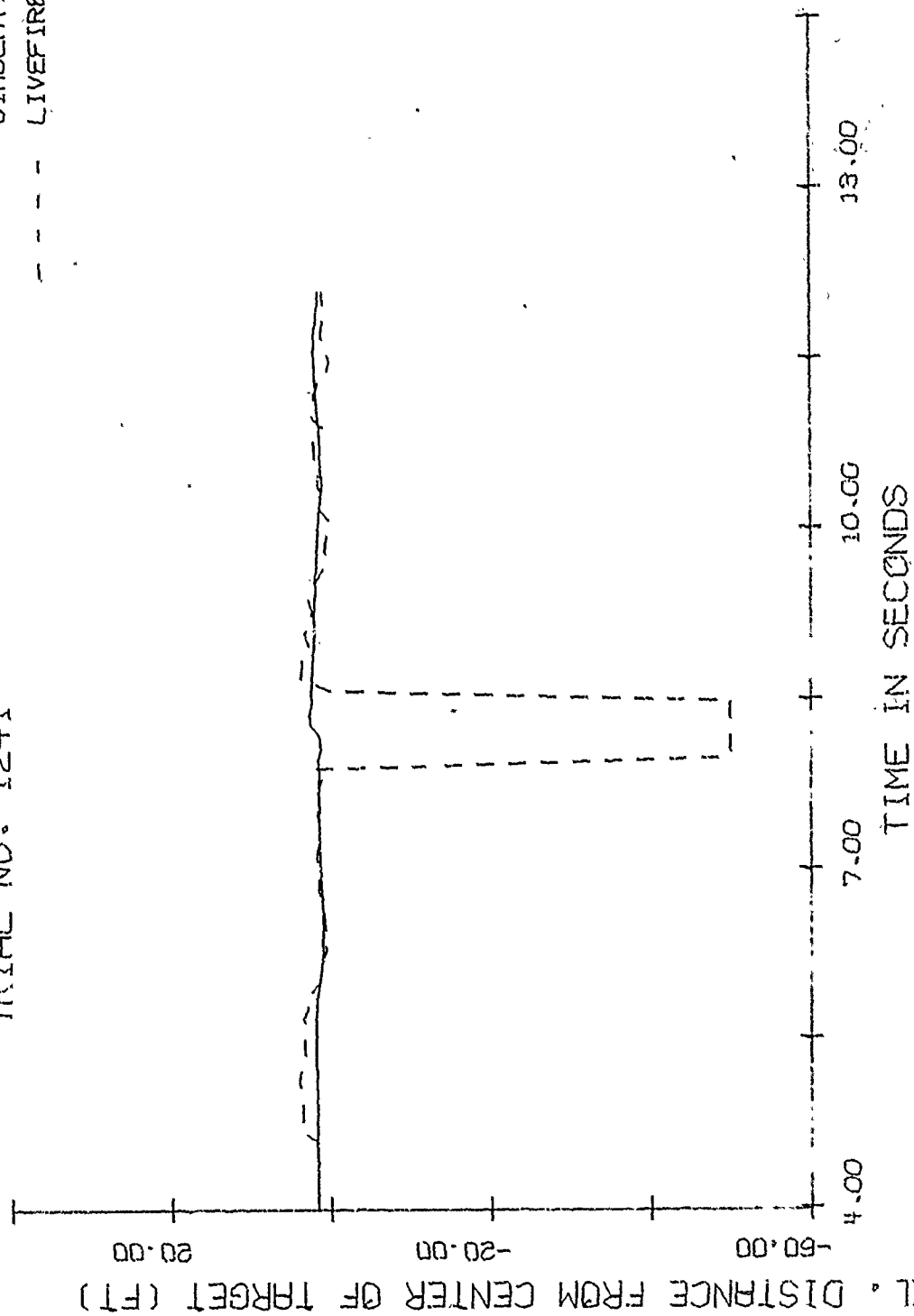
— SIMULATION
- - - LIVEFIRE

TARGET RANGE - 2855 METERS
TRIAL NO. 1240



TARGET RANGE - 2855 METERS
 TRIAL NO. 1241

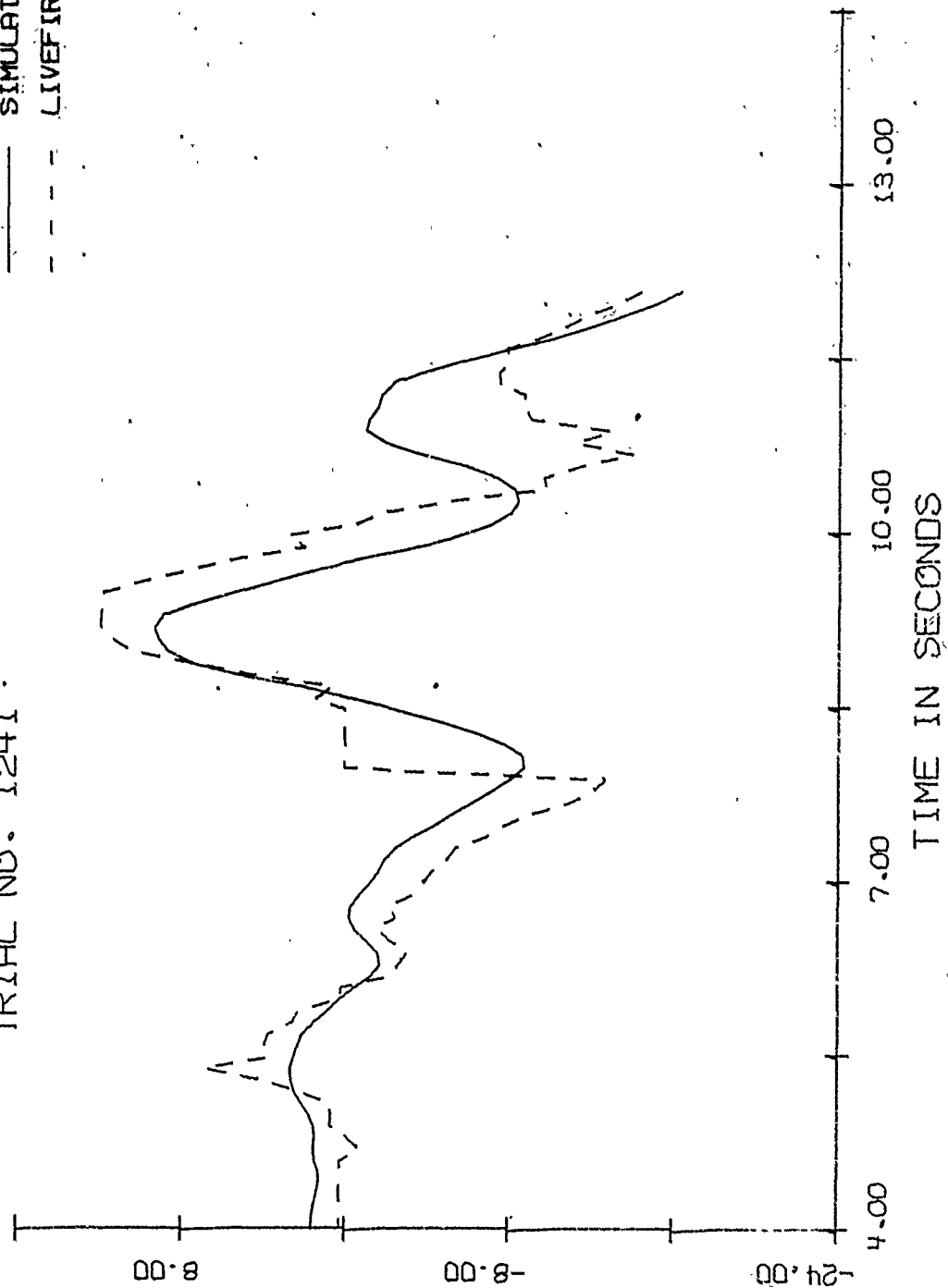
— SIMULATION
 - - - LIVEFIRE



AZ. DISTANCE FROM CENTER OF TARGET (FT)

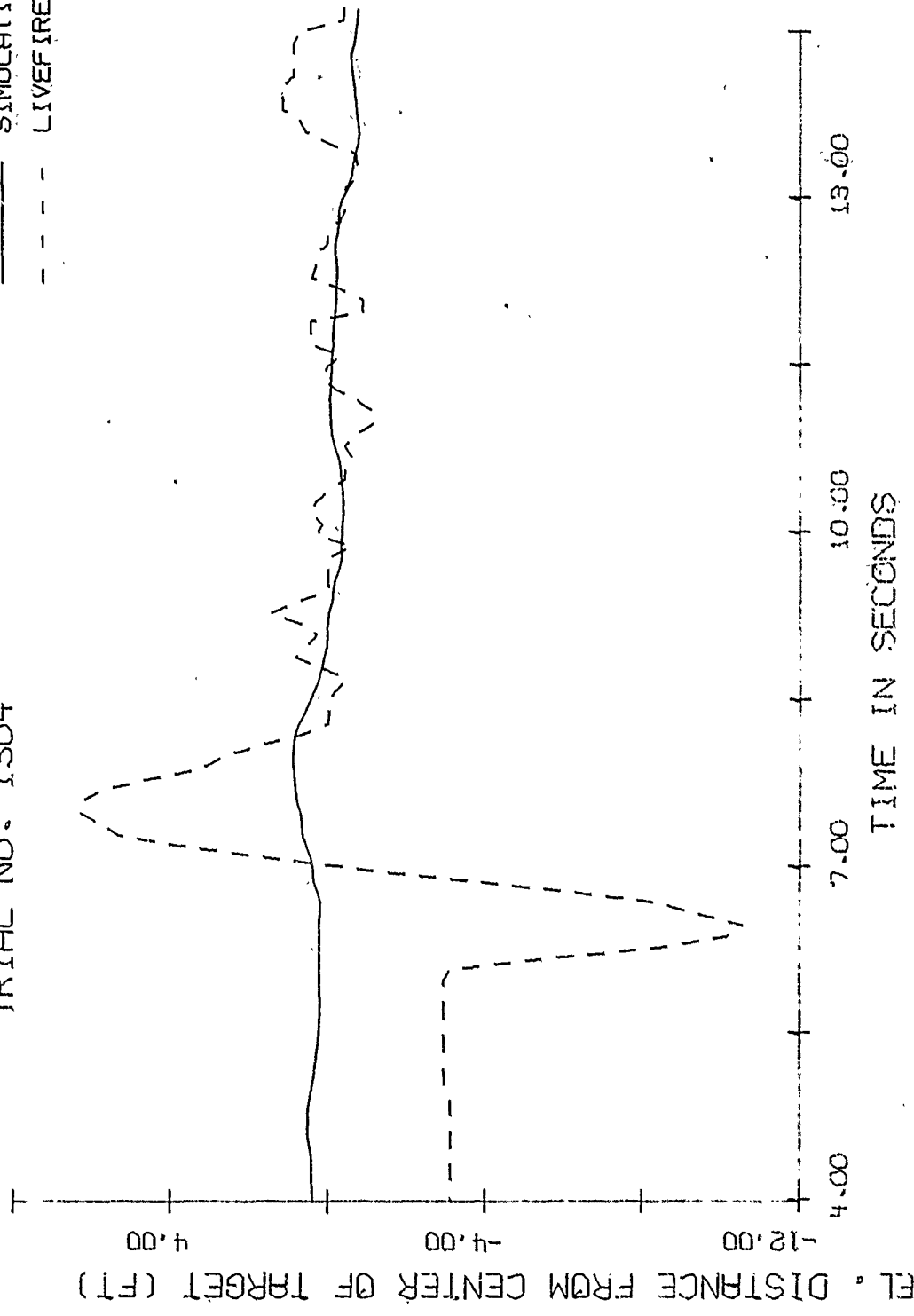
— SIMULATION
- - - LIVEFIRE

TARGET RANGE - 2855 METERS
TRIAL NO. 1241



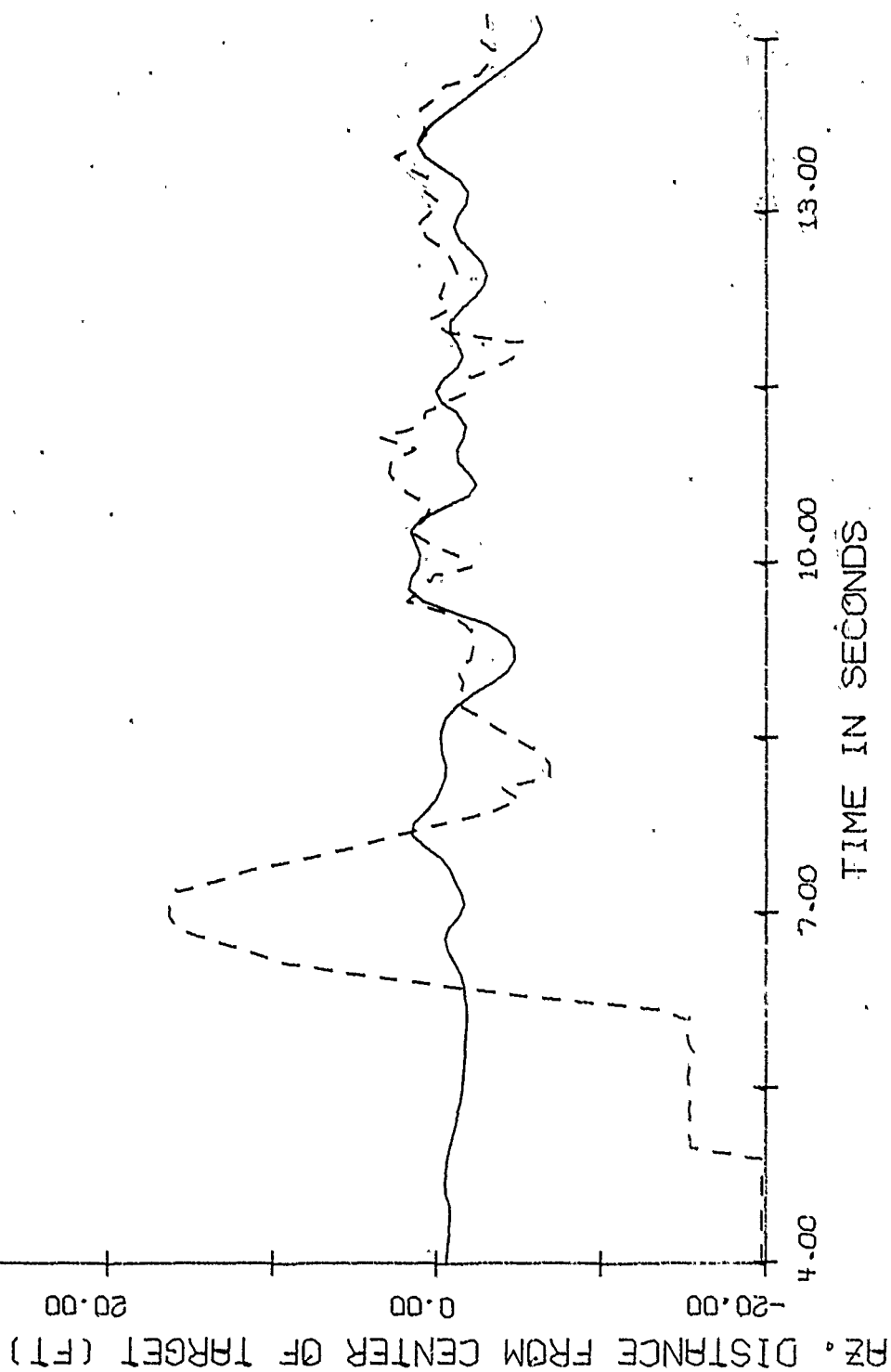
TARGET RANGE - 2855 METERS
TRIAL NO. 1304

— SIMULATION
- - - LIVEFIRE



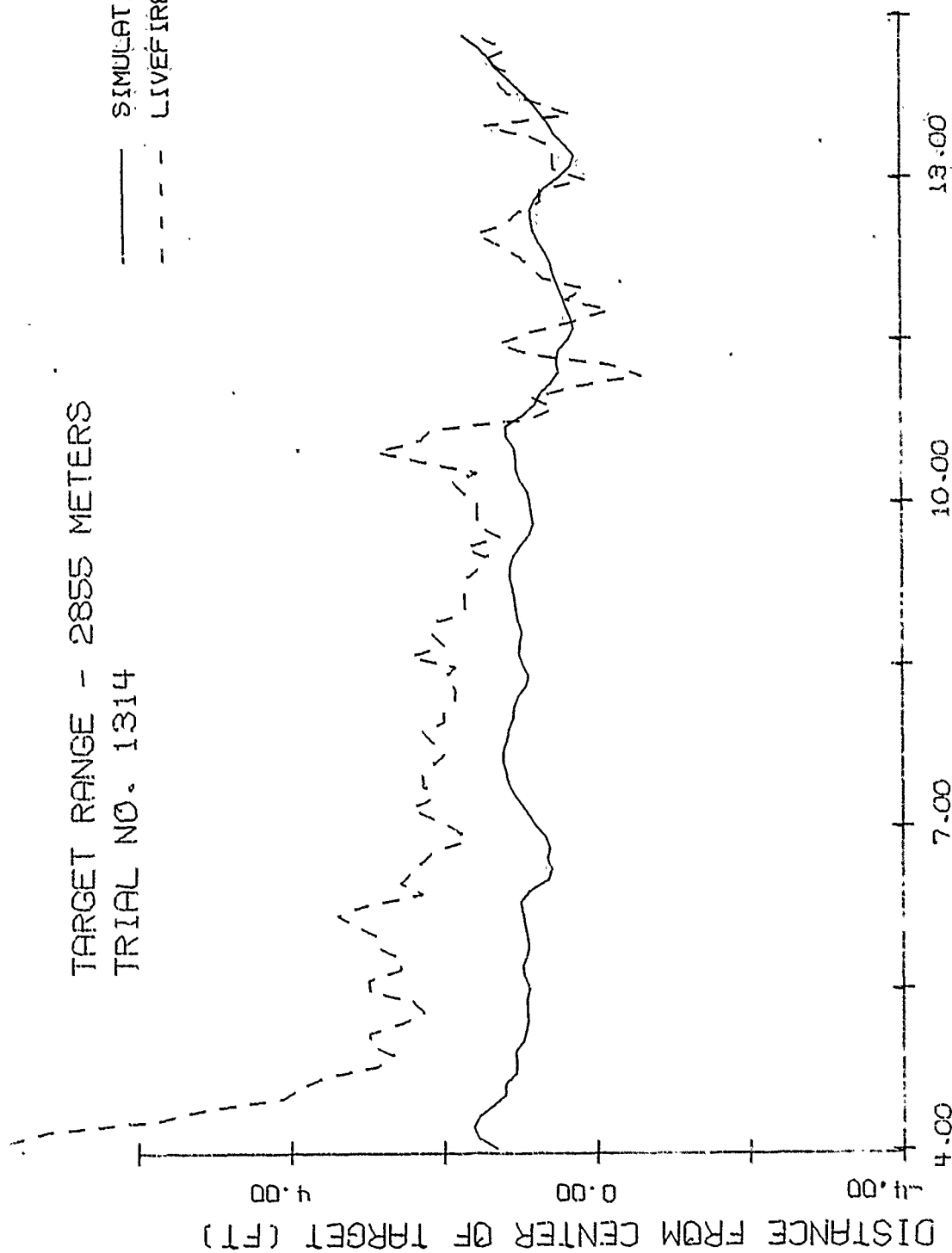
TARGET RANGE - 2855 METERS
TRIAL NO. 1304

— SIMULATION
- - - LIVEFIRE



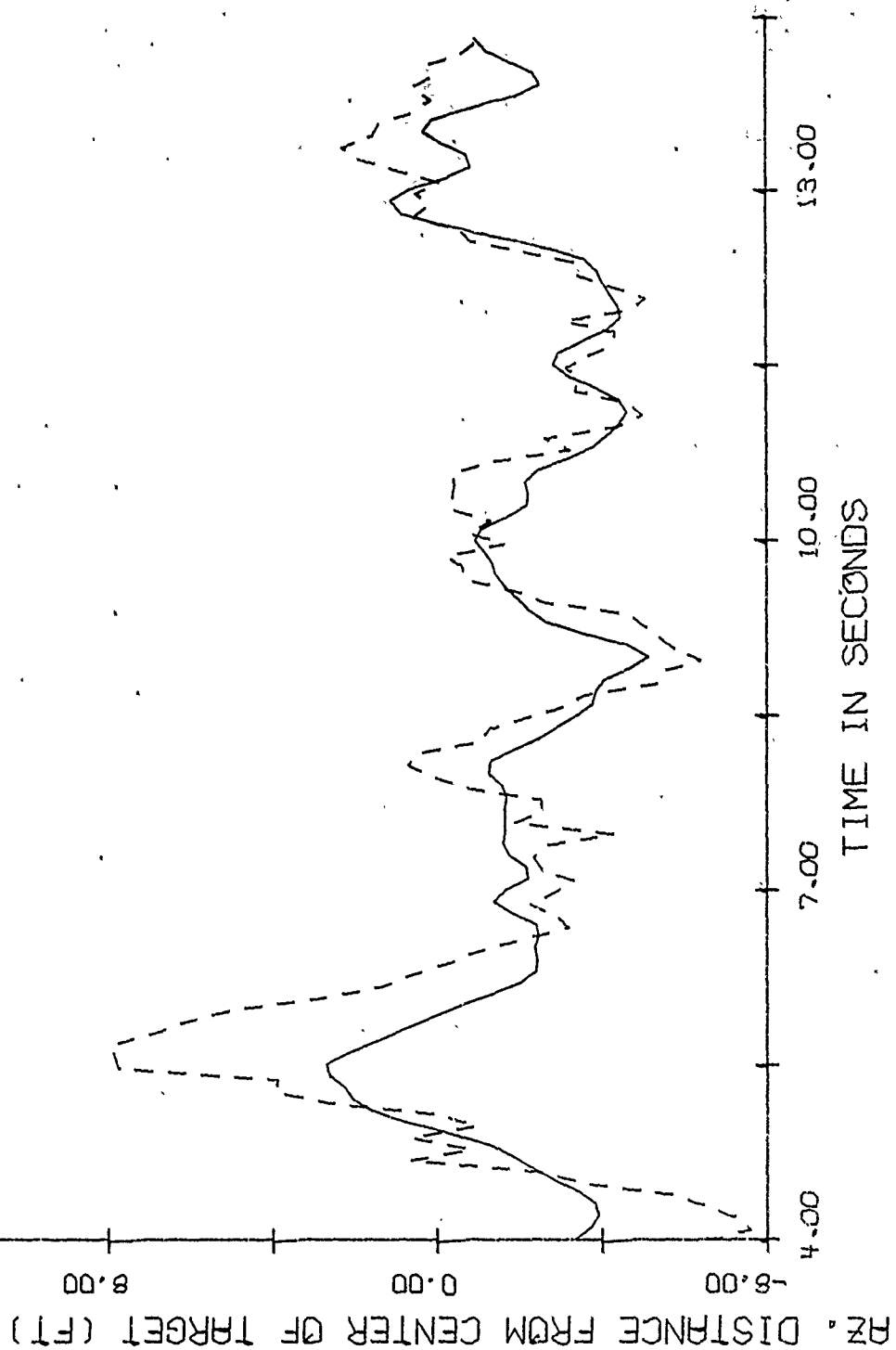
TARGET RANGE - 2855 METERS
TRIAL NO. 1314

— SIMULATION
- - - LIVEFIRE



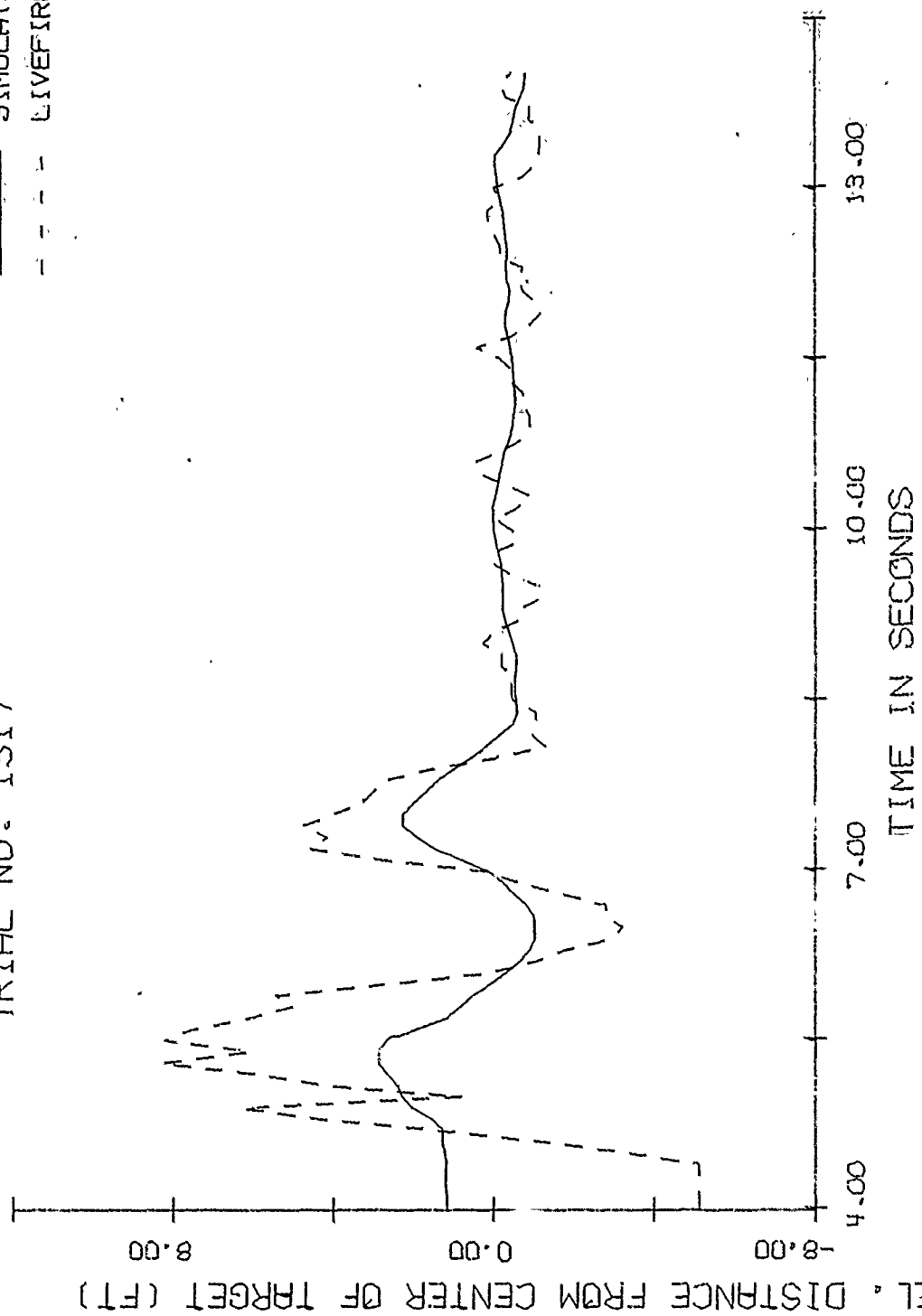
TARGET RANGE - 2855 METERS
TRIAL NO. 1314

— SIMULATION
- - - LIVEFIRE



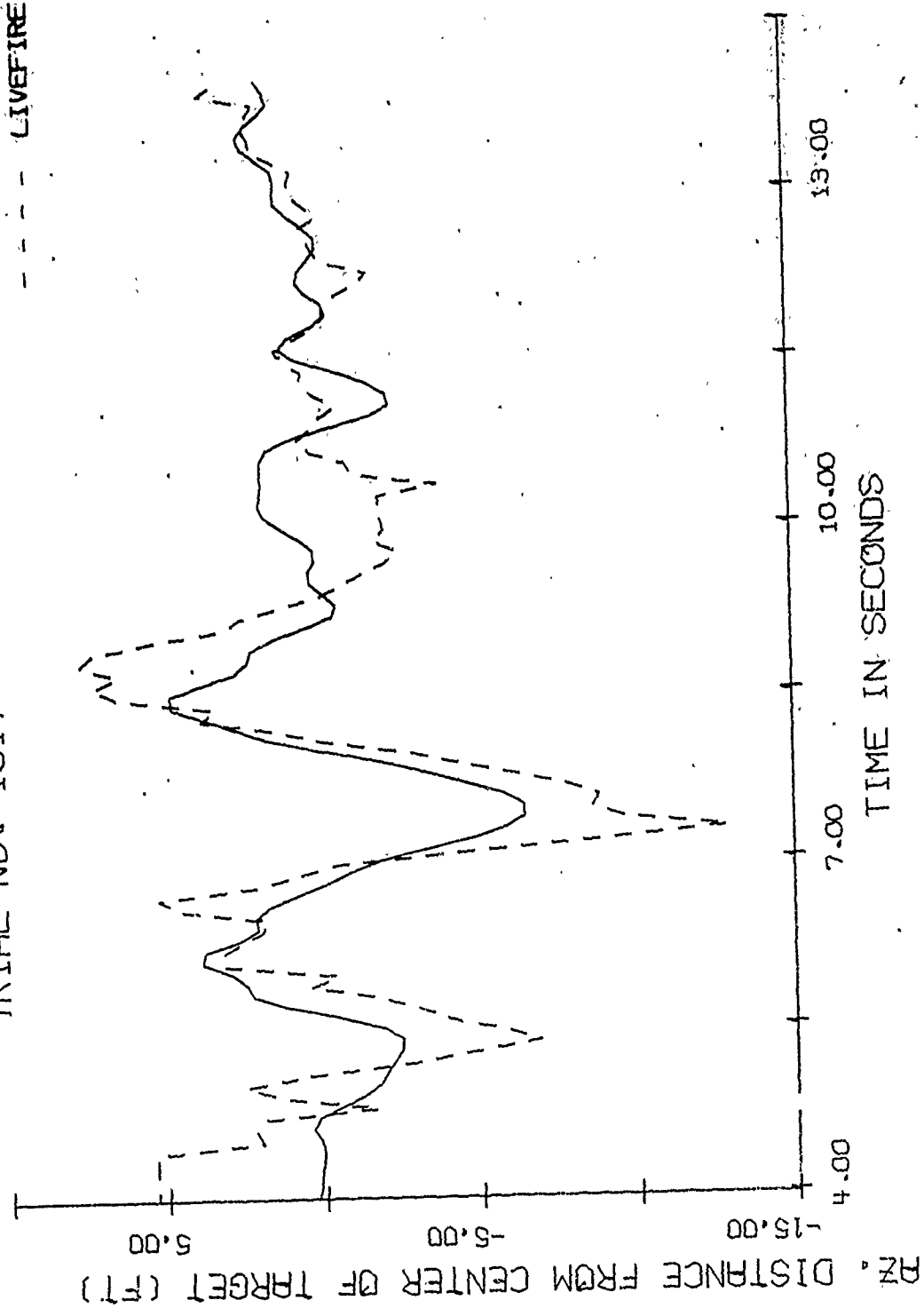
TARGET RANGE - 2855 METERS
TRIAL NO. 1317

— SIMULATION
- - - LIVEFIRE



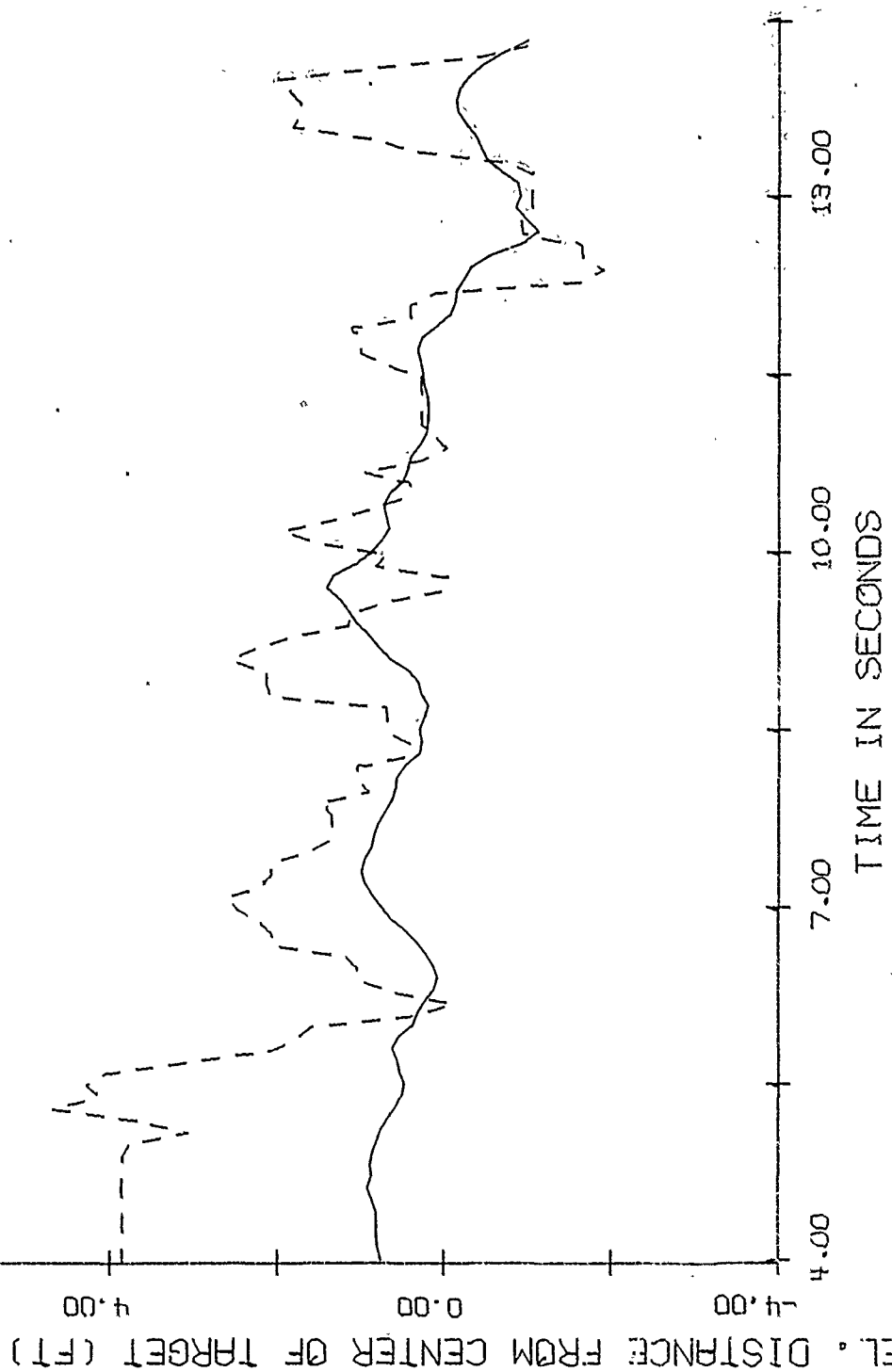
TARGET RANGE - 2855 METERS
TRIAL NO. 1317

— SIMULATION
- - - LIVEFIRE



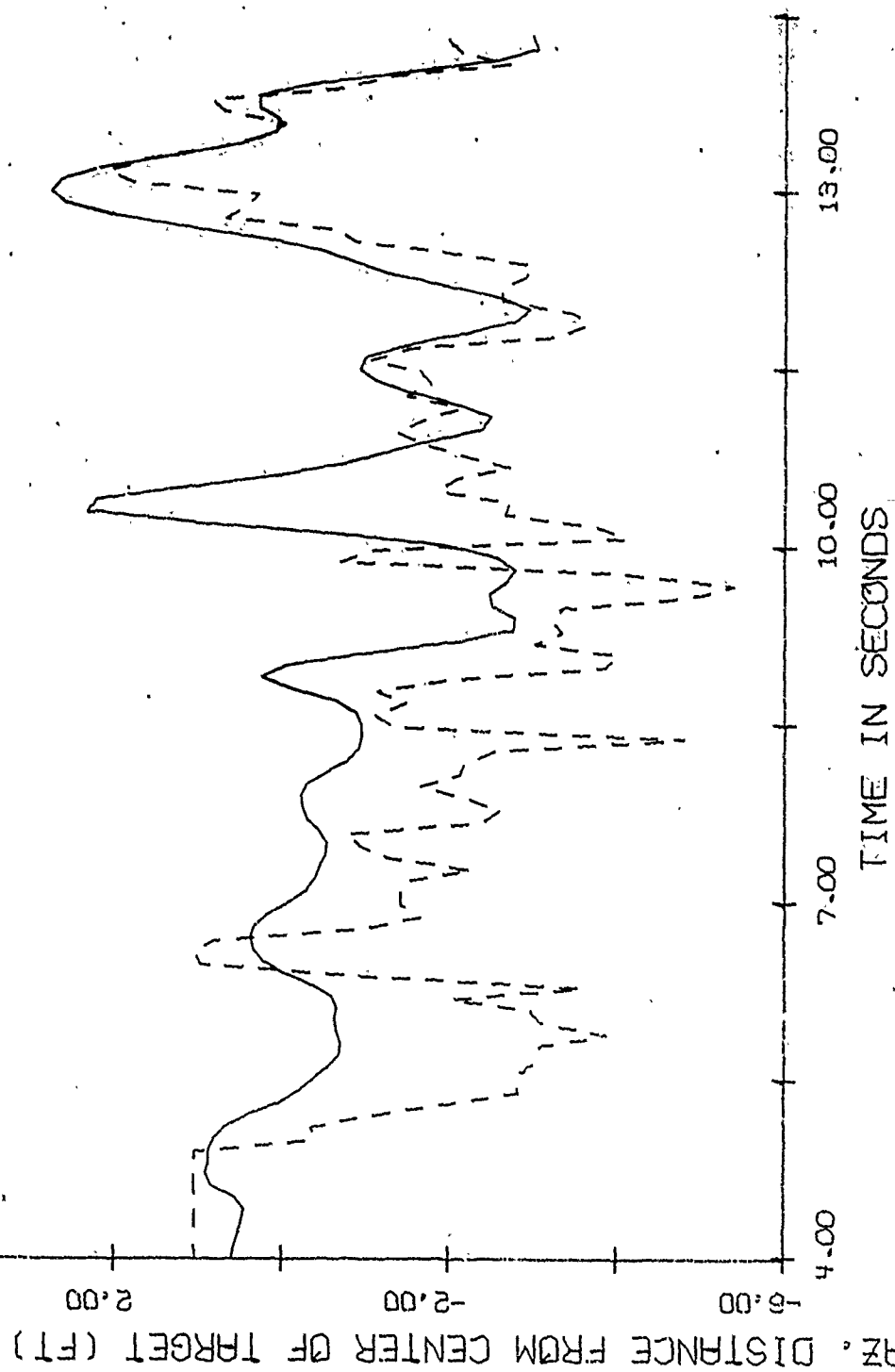
TARGET RANGE - 2855 METERS
TRIAL NO. 1318

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1318

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1324

— SIMULATION
- - - LIVEFIRE

EL. DISTANCE FROM CENTER OF TARGET (FT)

4.00

0.00

4.00

7.00

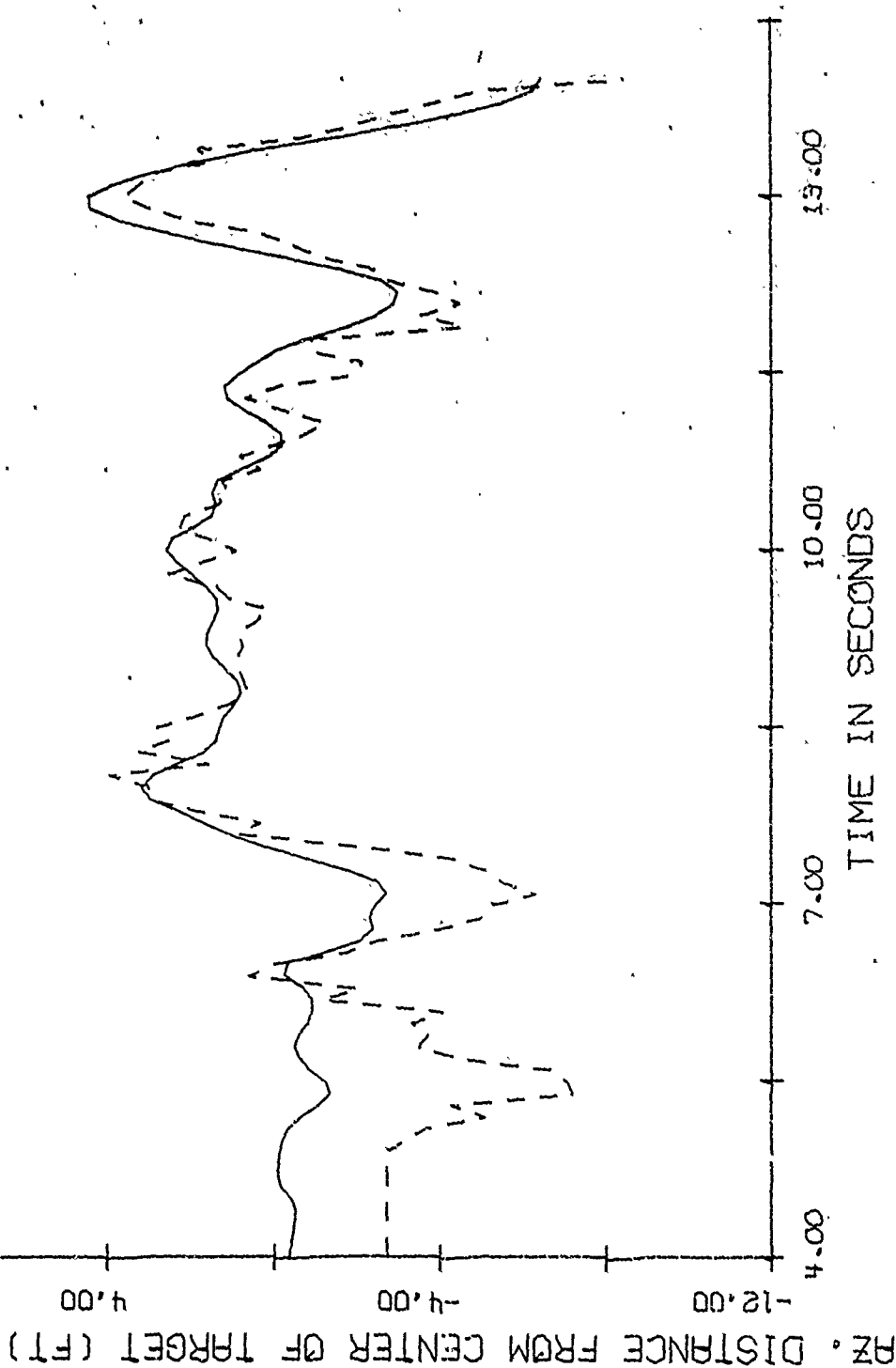
10.00

13.00

TIME IN SECONDS

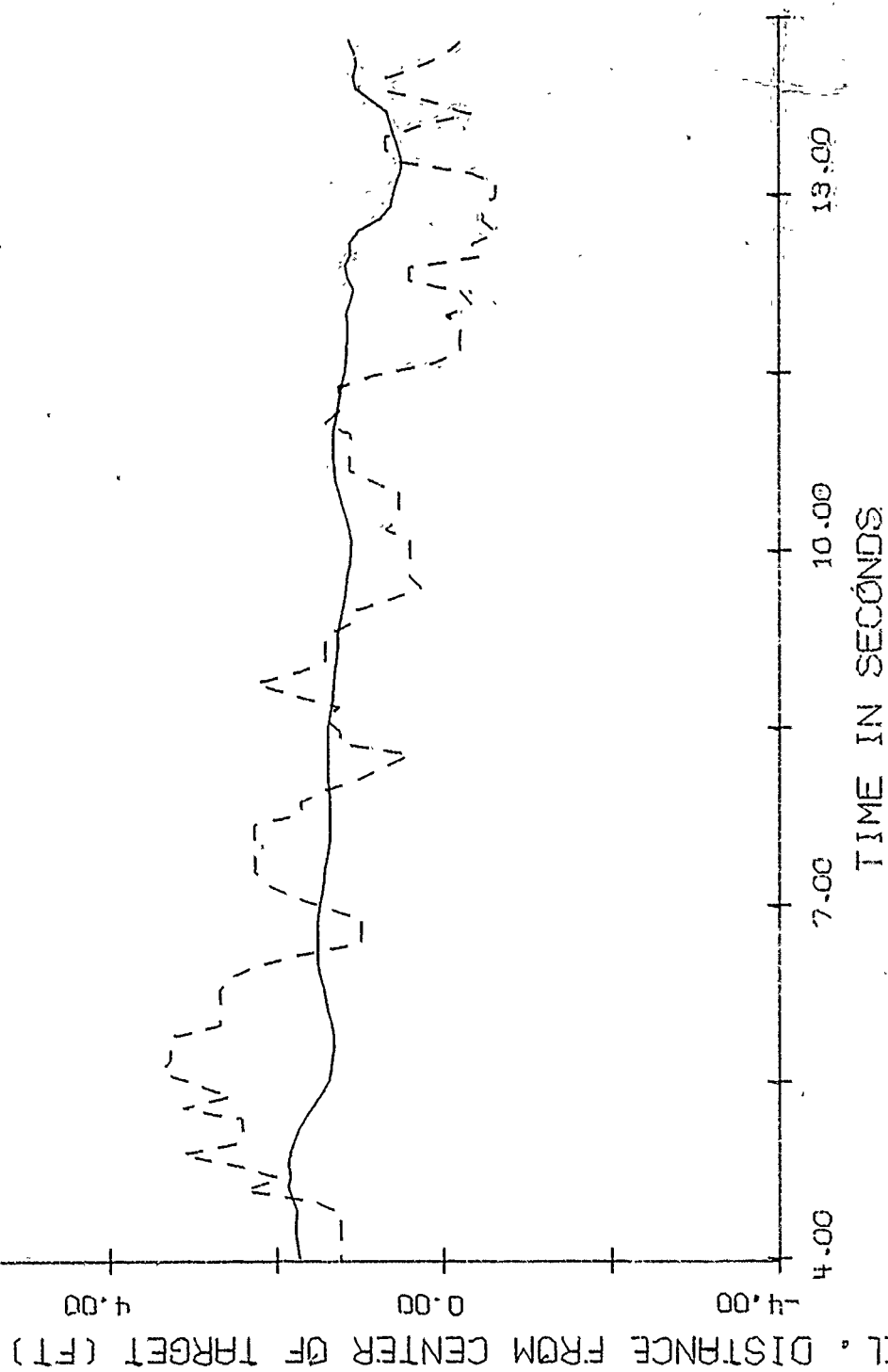
TARGET RANGE - 2855 METERS
TRIAL NO. 1324

— SIMULATION
- - - LIVEFIRE



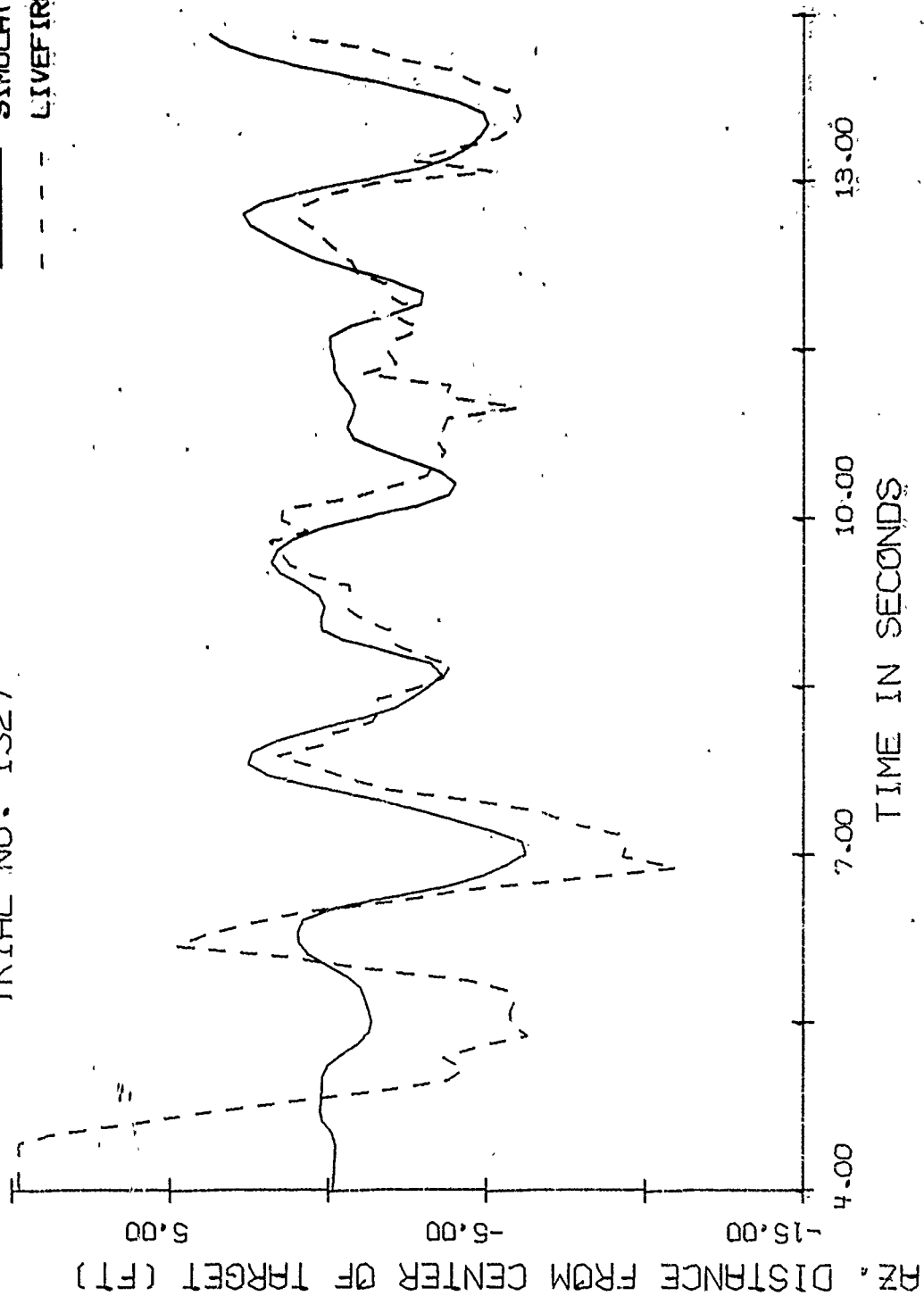
TARGET RANGE - 2855 METERS
TRIAL NO. 1327

— SIMULATION
- - - LIVEFIRE



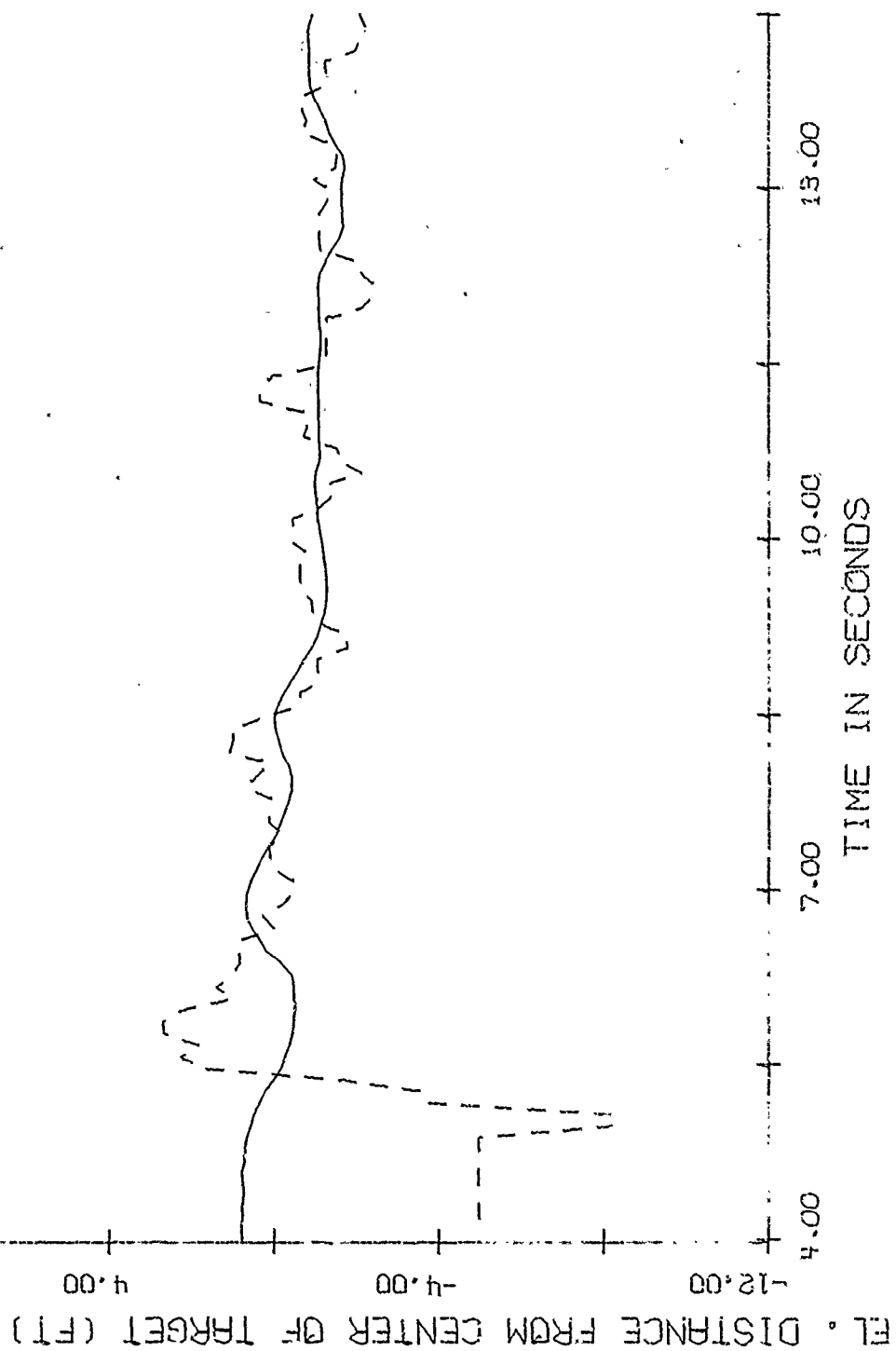
TARGET RANGE - 2855 METERS
TRIAL NO. 1327

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1336

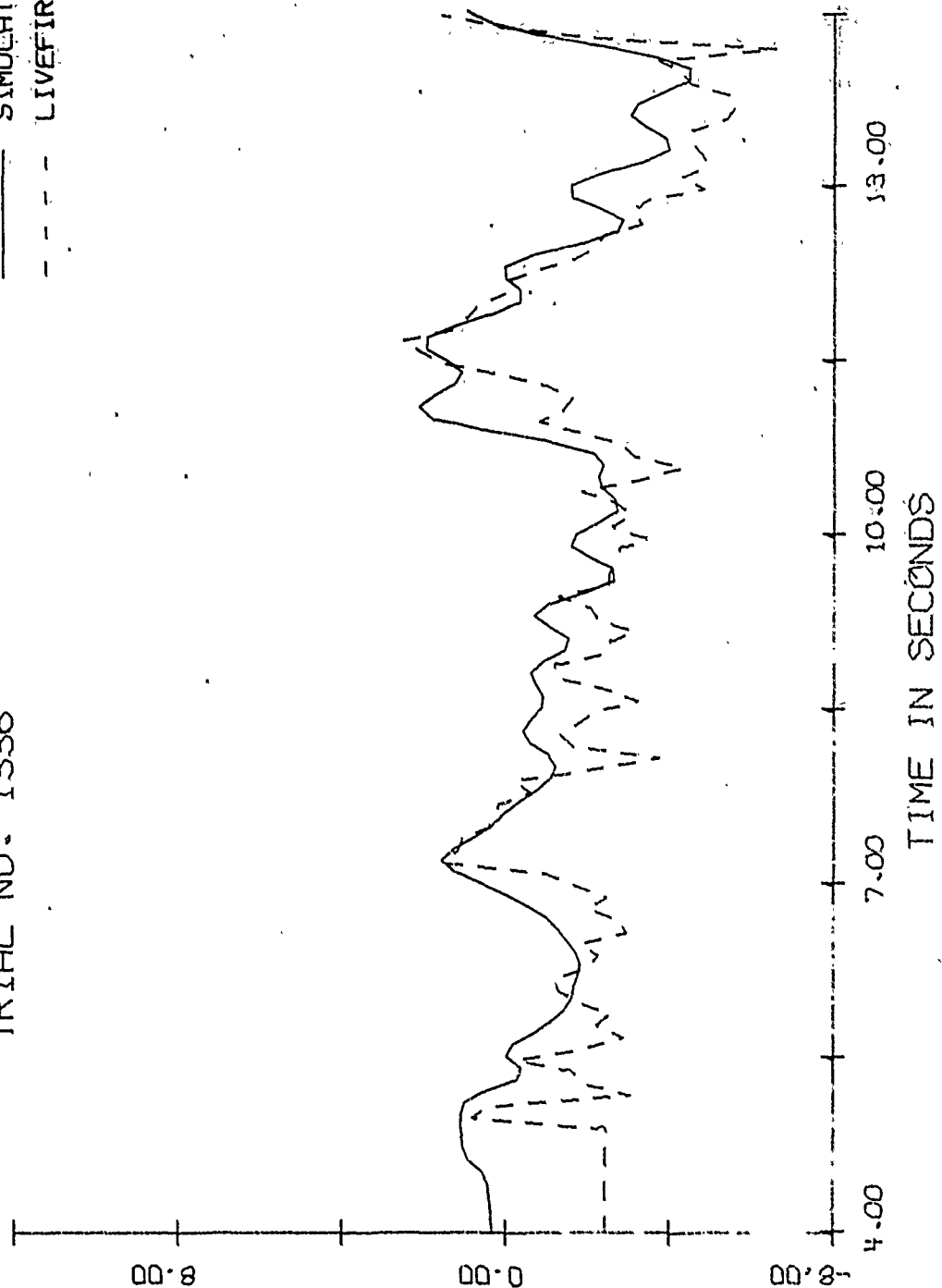
— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1336

— SIMULATION
- - - LIVEFIRE

AZ. DISTANCE FROM CENTER OF TARGET (FT)



TARGET RANGE - 2855 METERS
TRIAL NO. 1337

— SIMULATION
- - - LIVEFIRE

EL. DISTANCE FROM CENTER OF TARGET (FT)

4.00 20.00 60.00

4.00

7.00

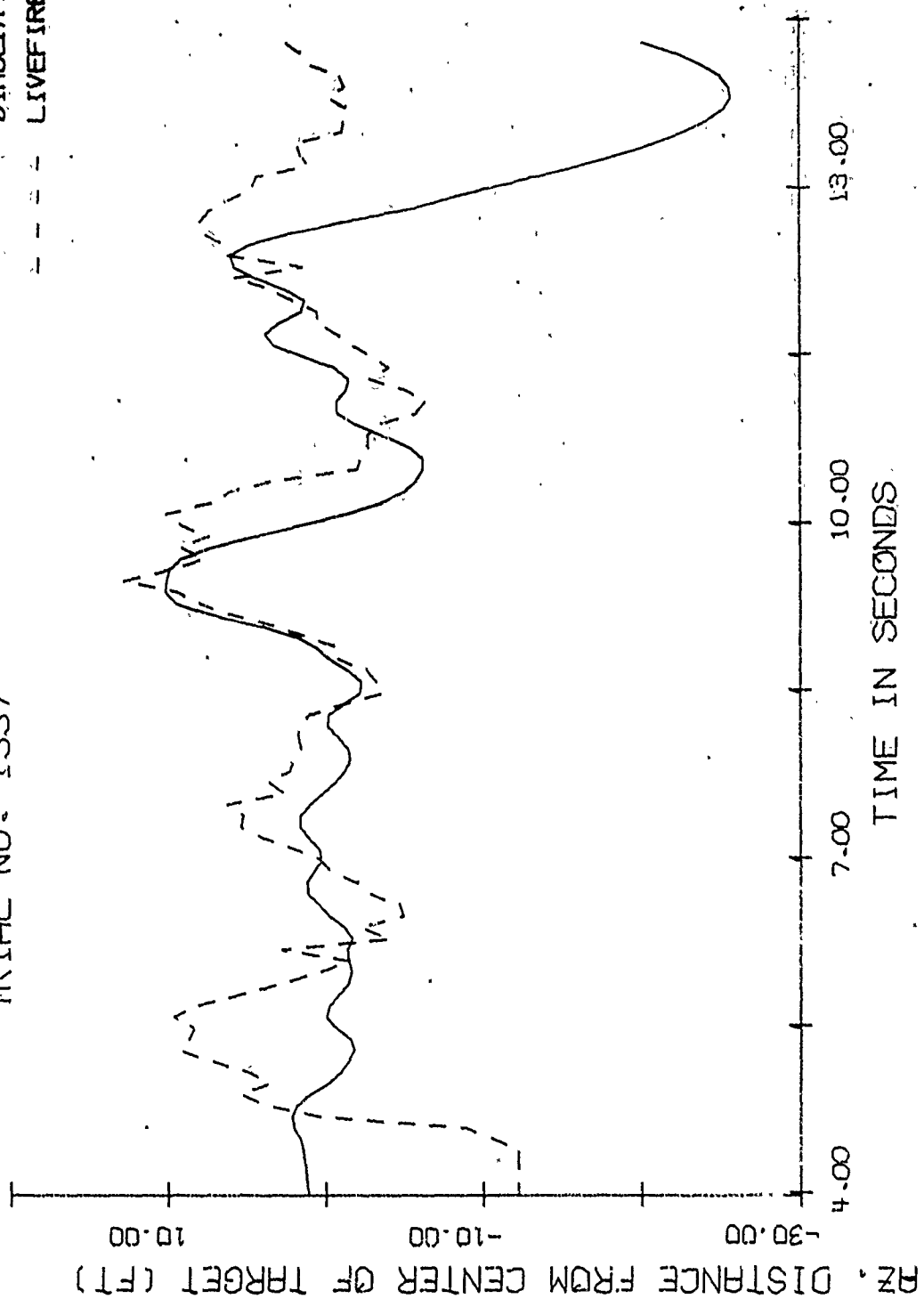
10.00

13.00

TIME IN SECONDS

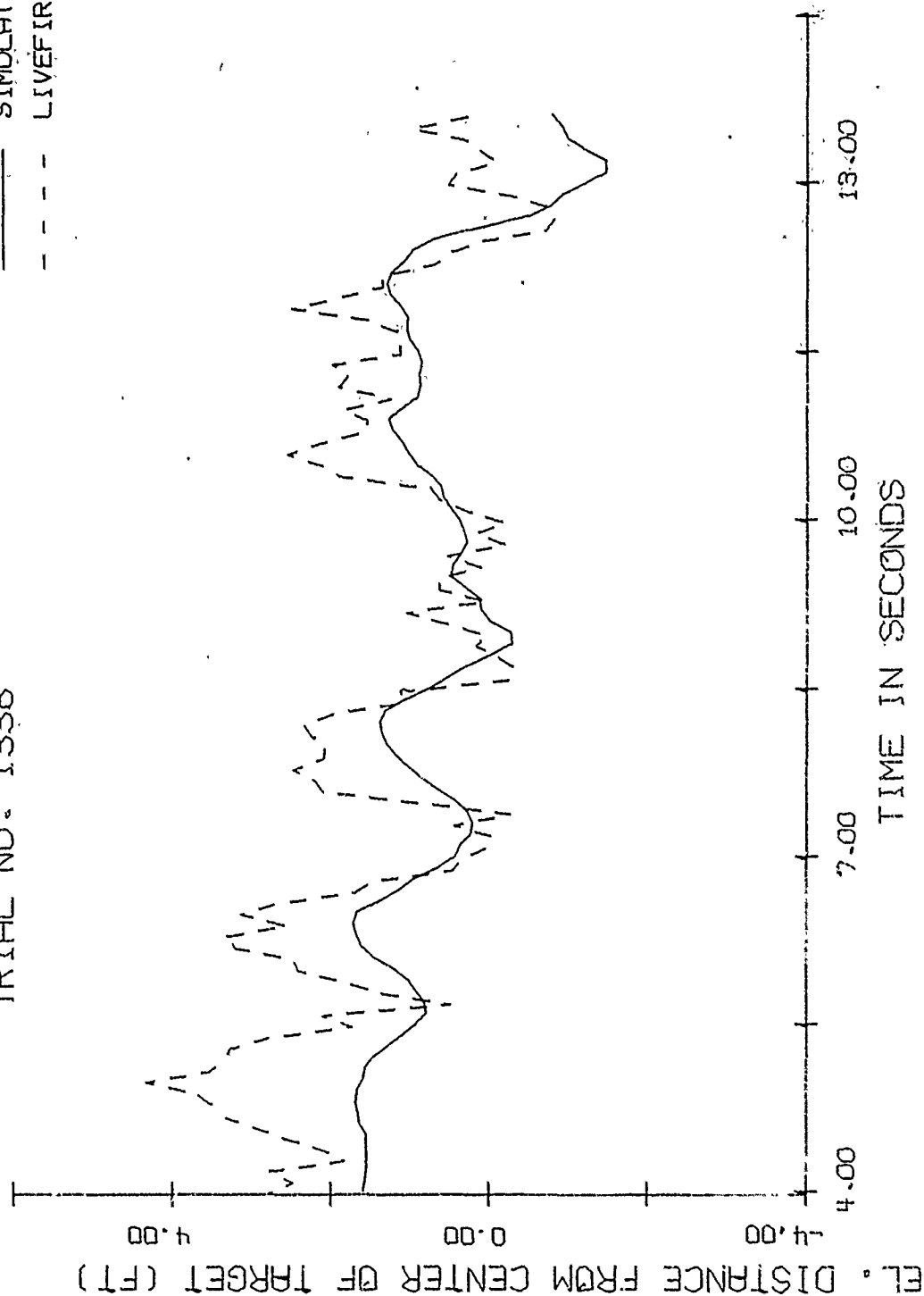
TARGET RANGE - 2855 METERS
TRIAL NO. 1337

— SIMULATION
- - - LIVEFIRE



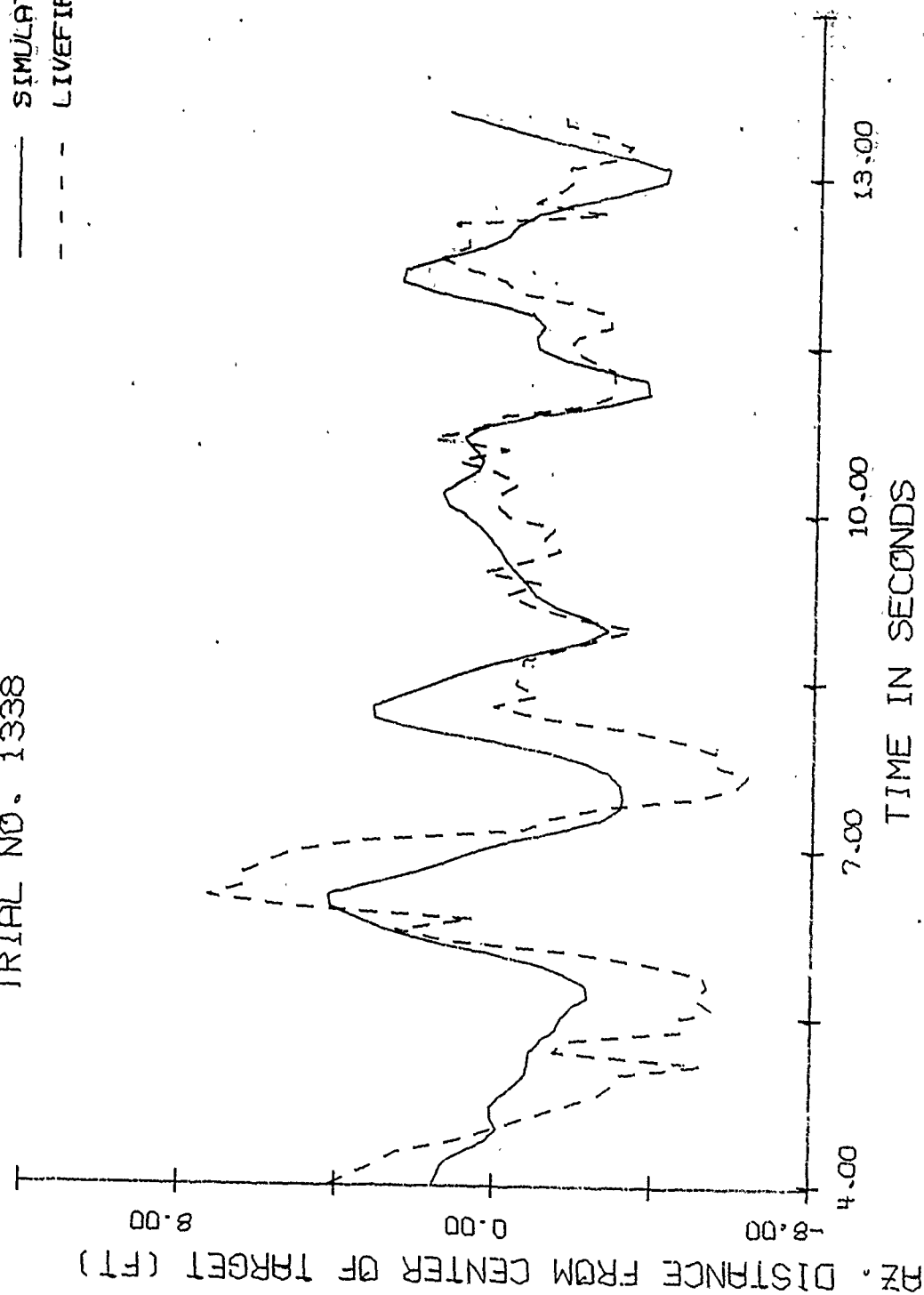
TARGET RANGE - 2855 METERS
 TRIAL NO. 1338

— SIMULATION
 --- LIVEFIRE



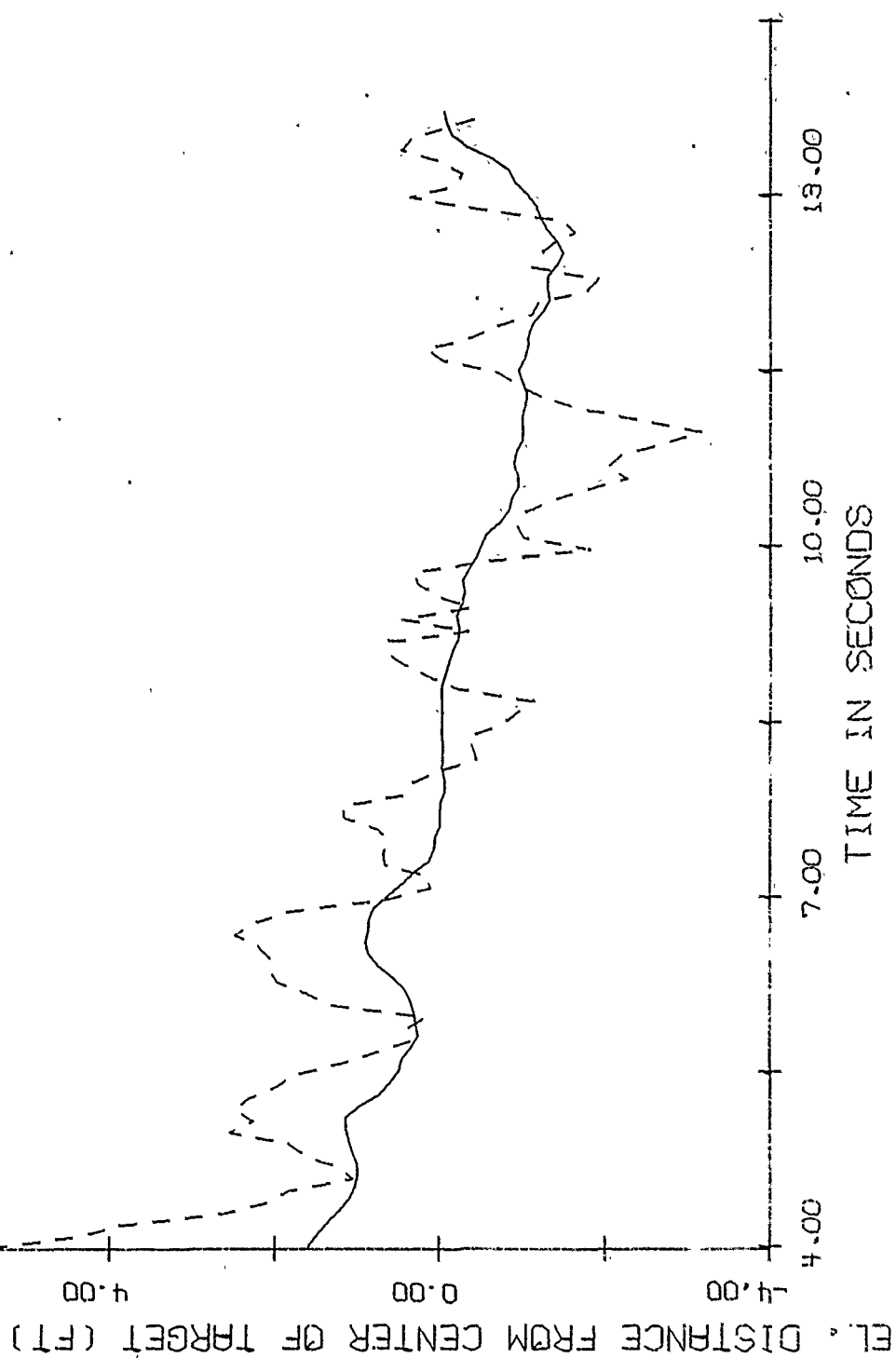
TARGET RANGE - 2855 METERS
TRIAL NO. 1338

— SIMULATION
- - - LIVEFIRE

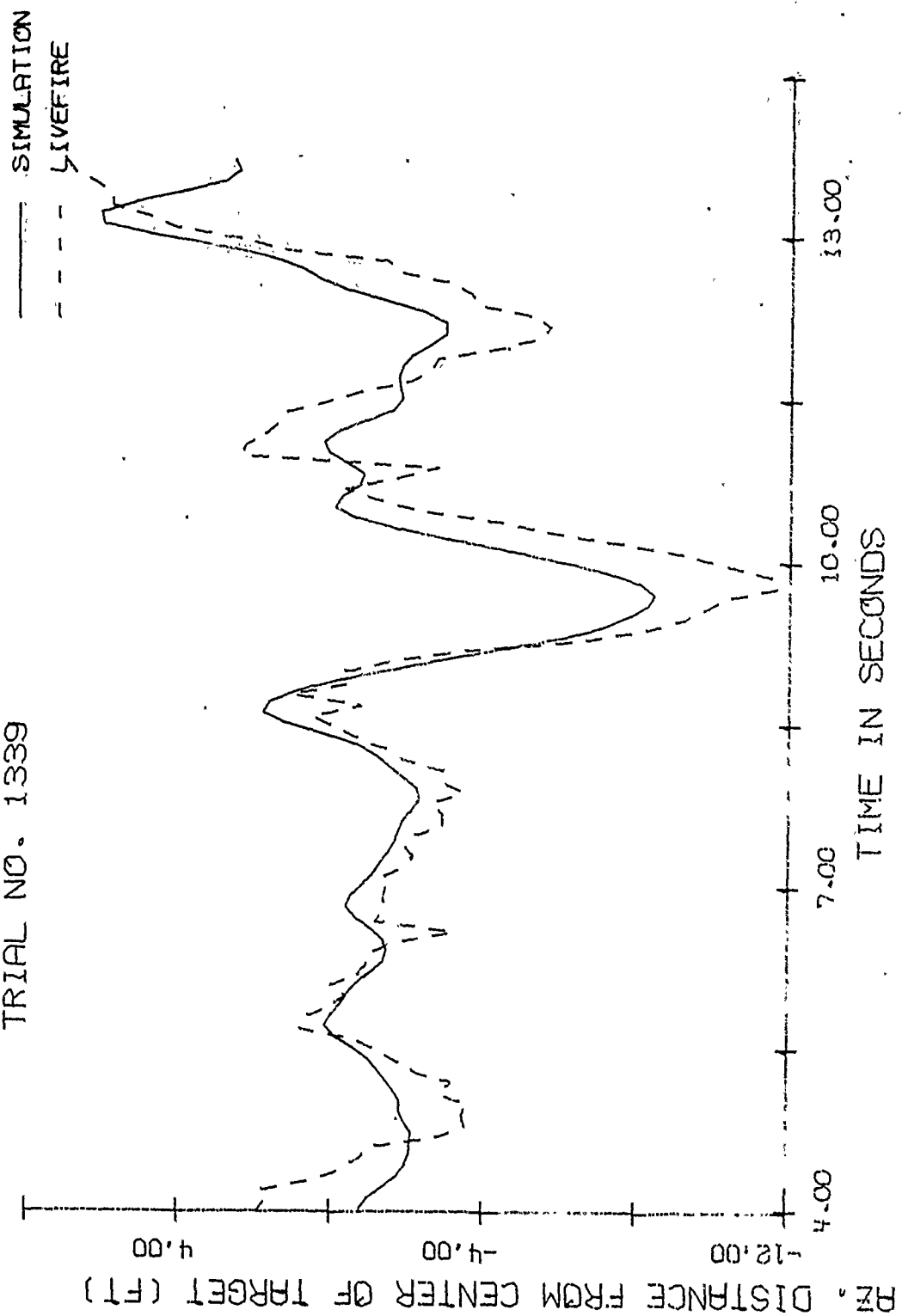


TARGET RANGE - 2855 METERS
TRIAL NO. 1339

— SIMULATION
- - - LIVEFIRE

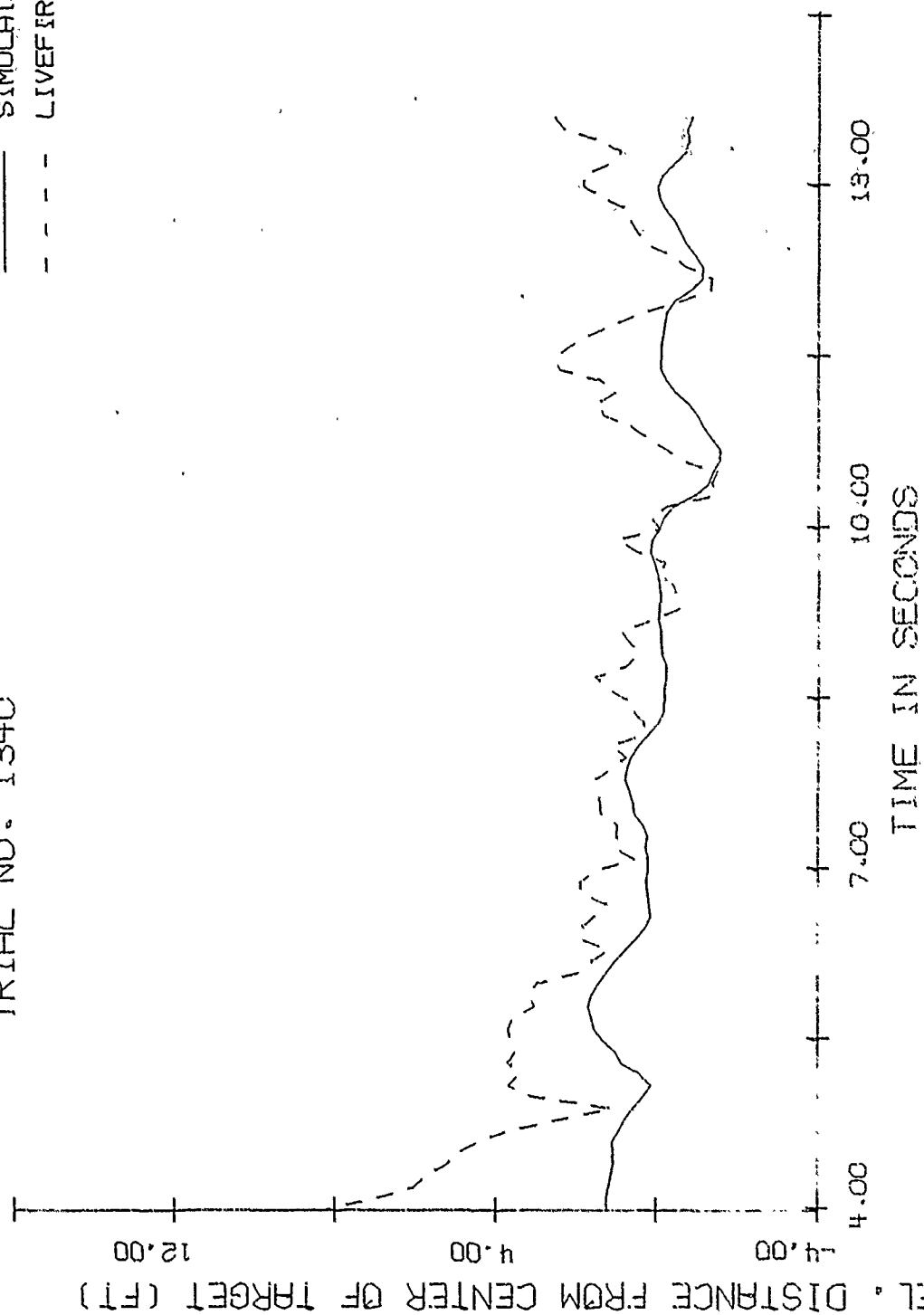


TARGET RANGE - 2855 METERS
TRIAL NO. 1339



TARGET RANGE - 2855 METERS
TRIAL NO. 1340

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1340

— SIMULATION
- - - LIVEFIRE

AZ. DISTANCE FROM CENTER OF TARGET (FT)

8.00
0.00
-8.00

TIME IN SECONDS

4.00
7.00
10.00
13.00

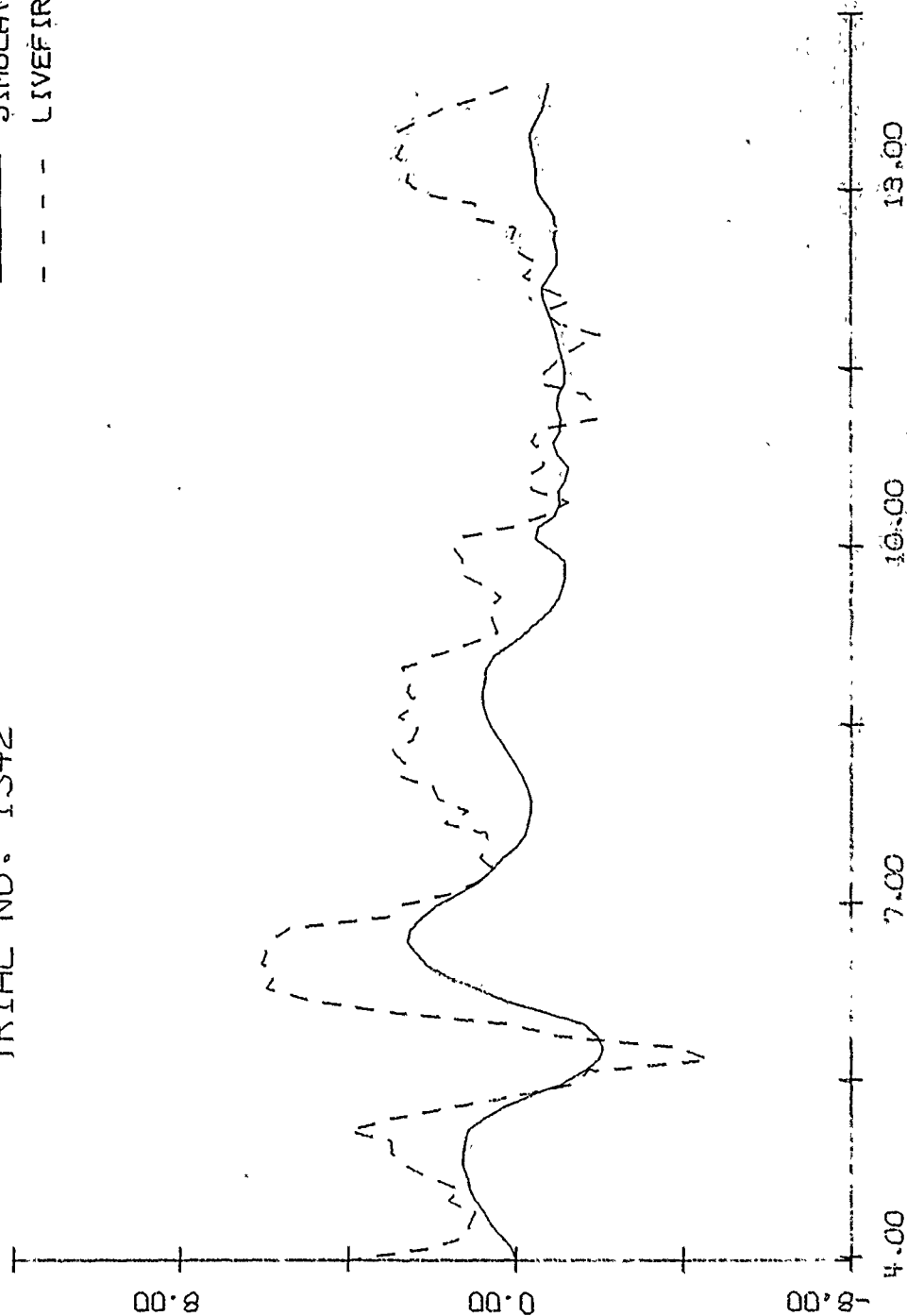
A-120

TARGET RANGE - 2855 METERS
TRIAL NO. 1342

— SIMULATION
- - - LIVEFIRE

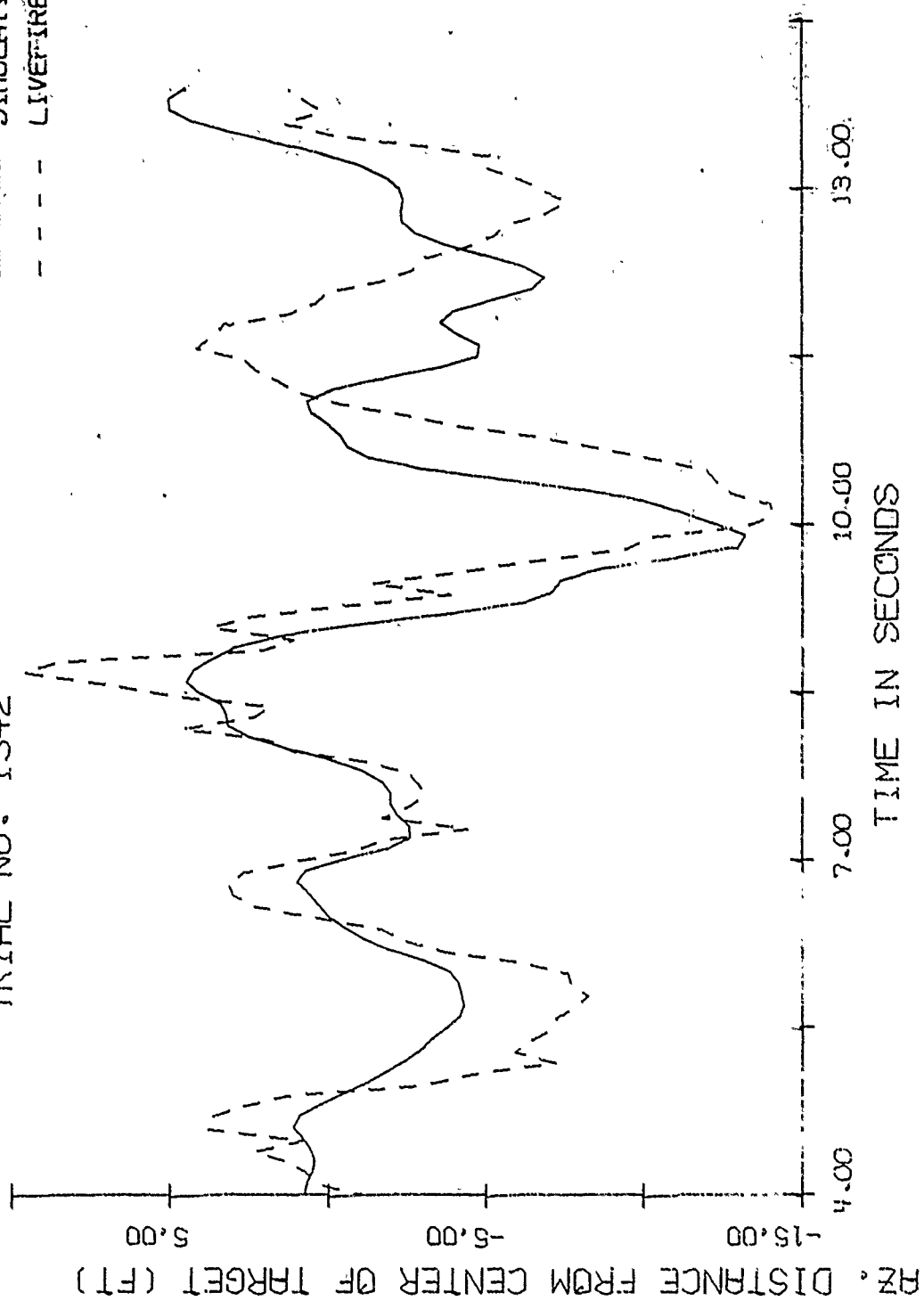
EL. DISTANCE FROM CENTER OF TARGET (FT)

TIME IN SECONDS



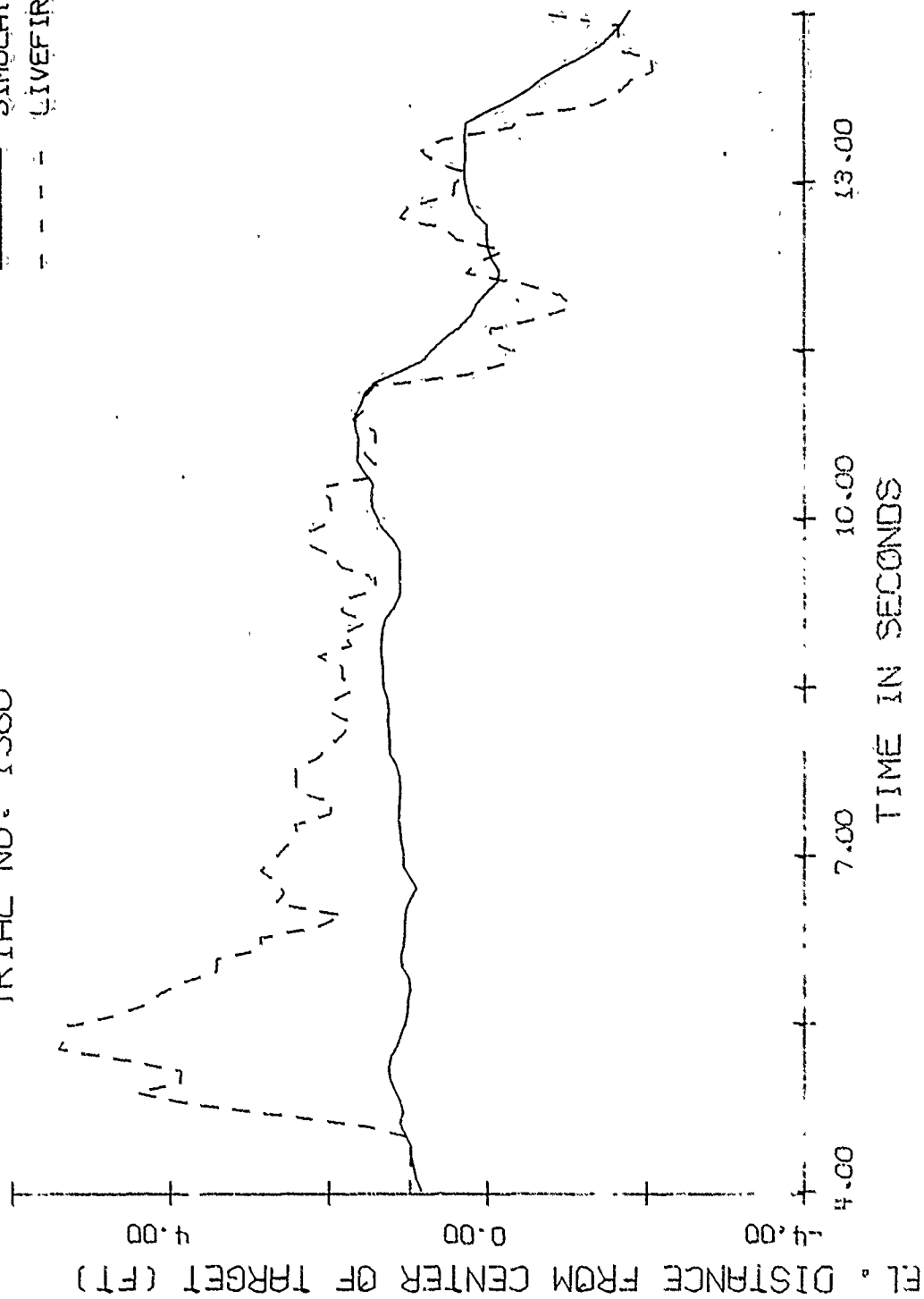
TARGET RANGE - 2855 METERS
TRIAL NO. 1342

— SIMULATION
- - - LIVEFIRE



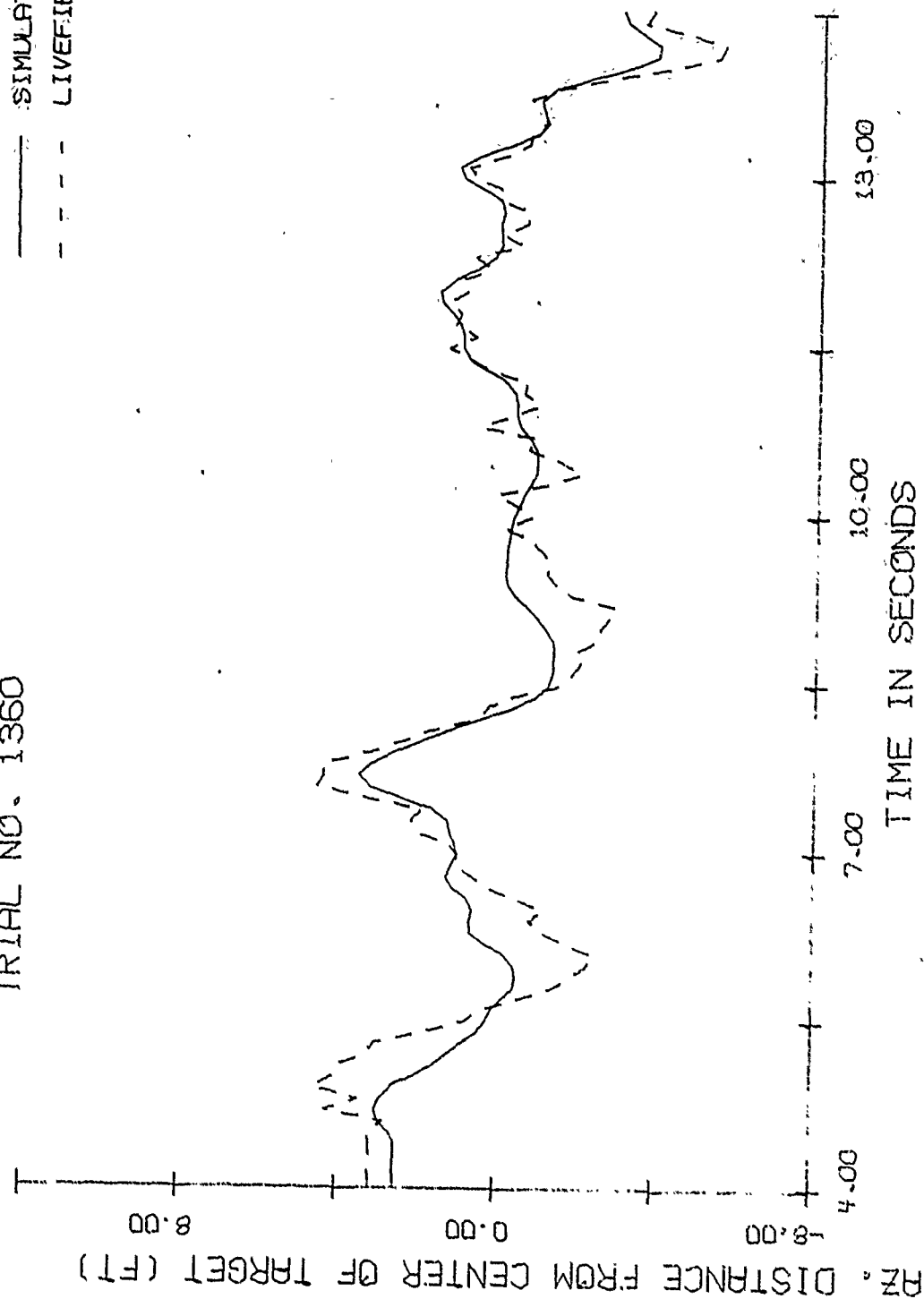
TARGET RANGE - 2855 METERS
TRIAL NO. 1360

SIMULATION
LIVE FIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1360

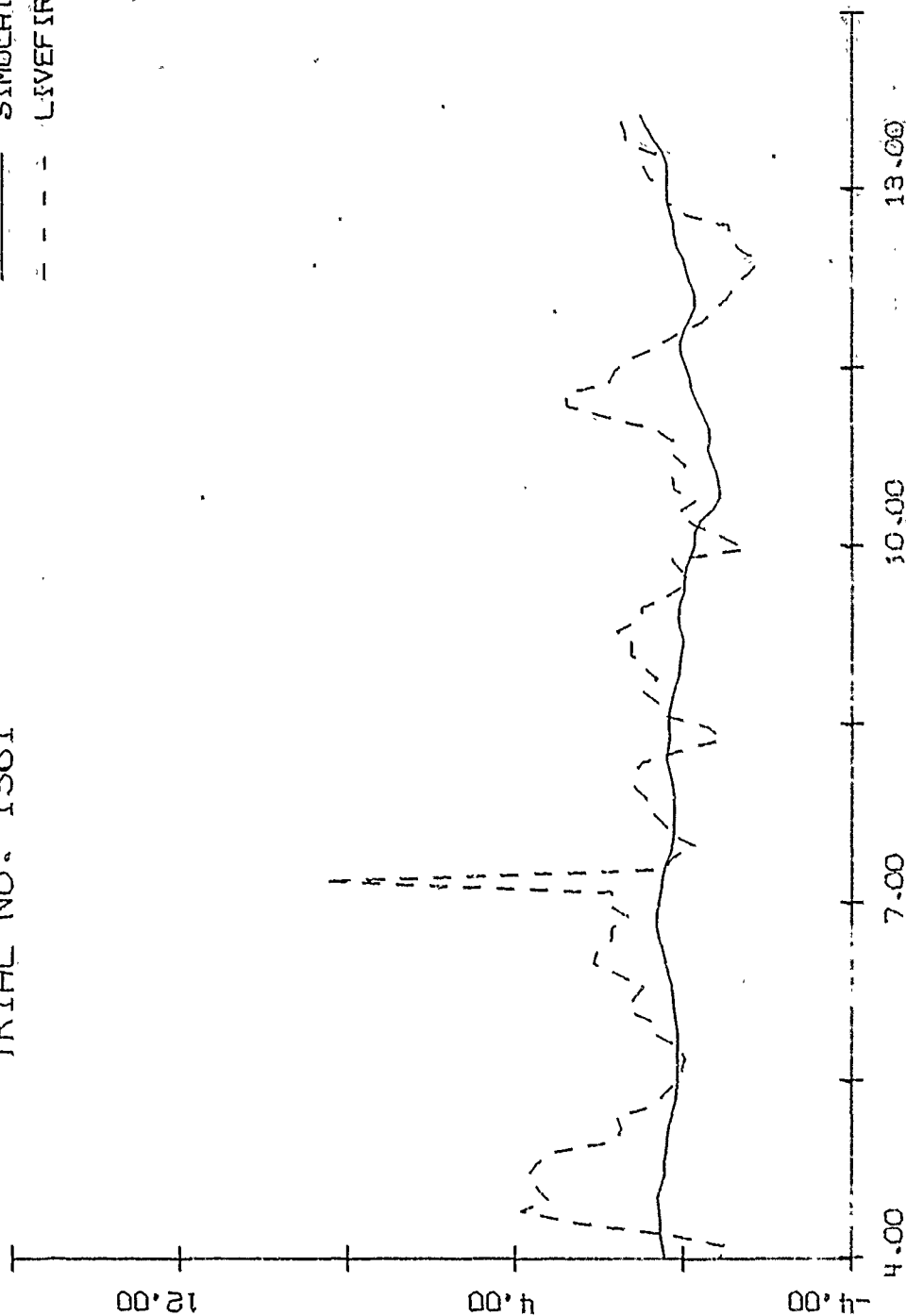
— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1361

— SIMULATION
- - - LIVEFIRE

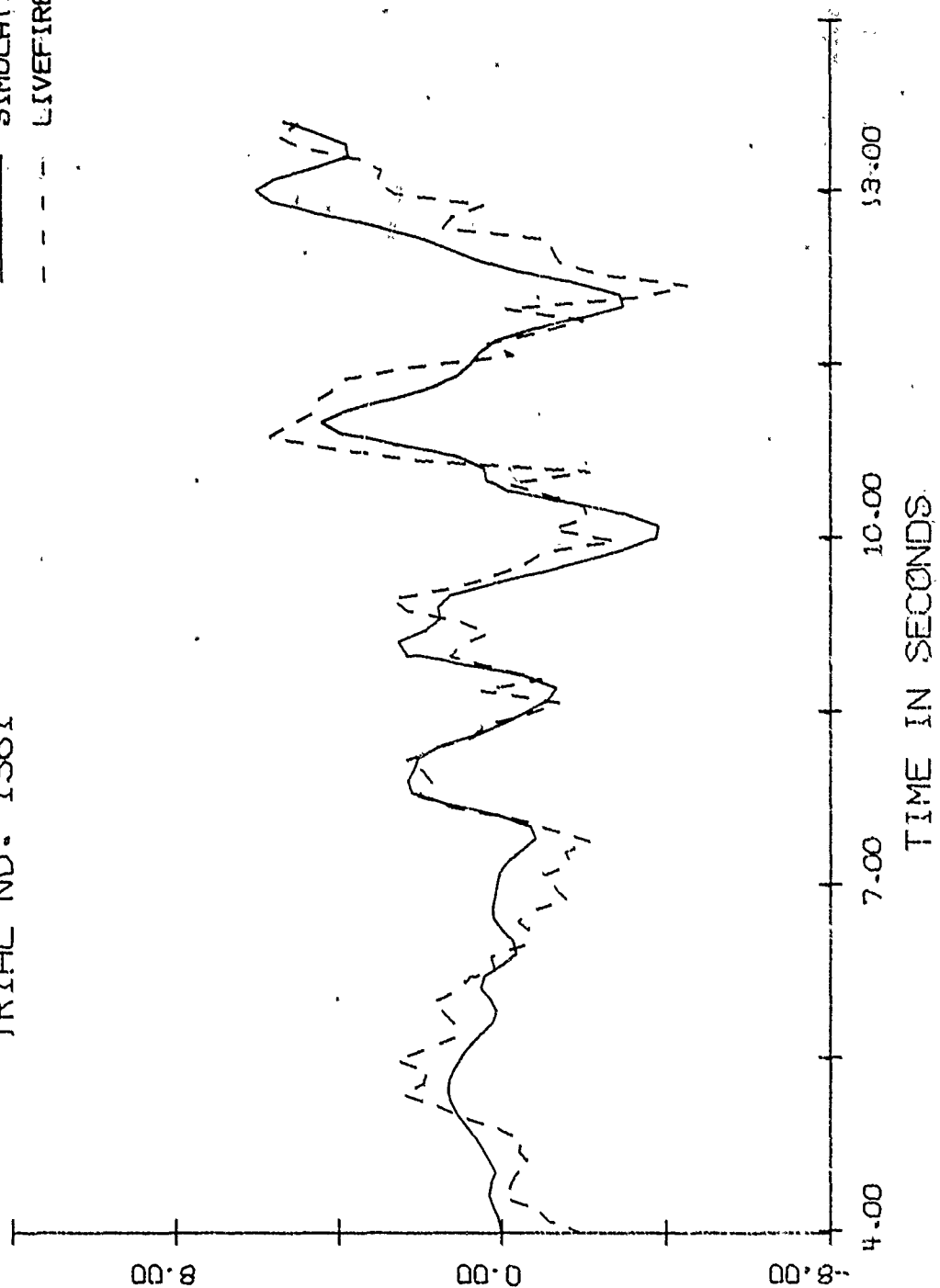
EL. DISTANCE FROM CENTER OF TARGET (FT)



TARGET RANGE - 2855 METERS
TRIAL NO. 1361

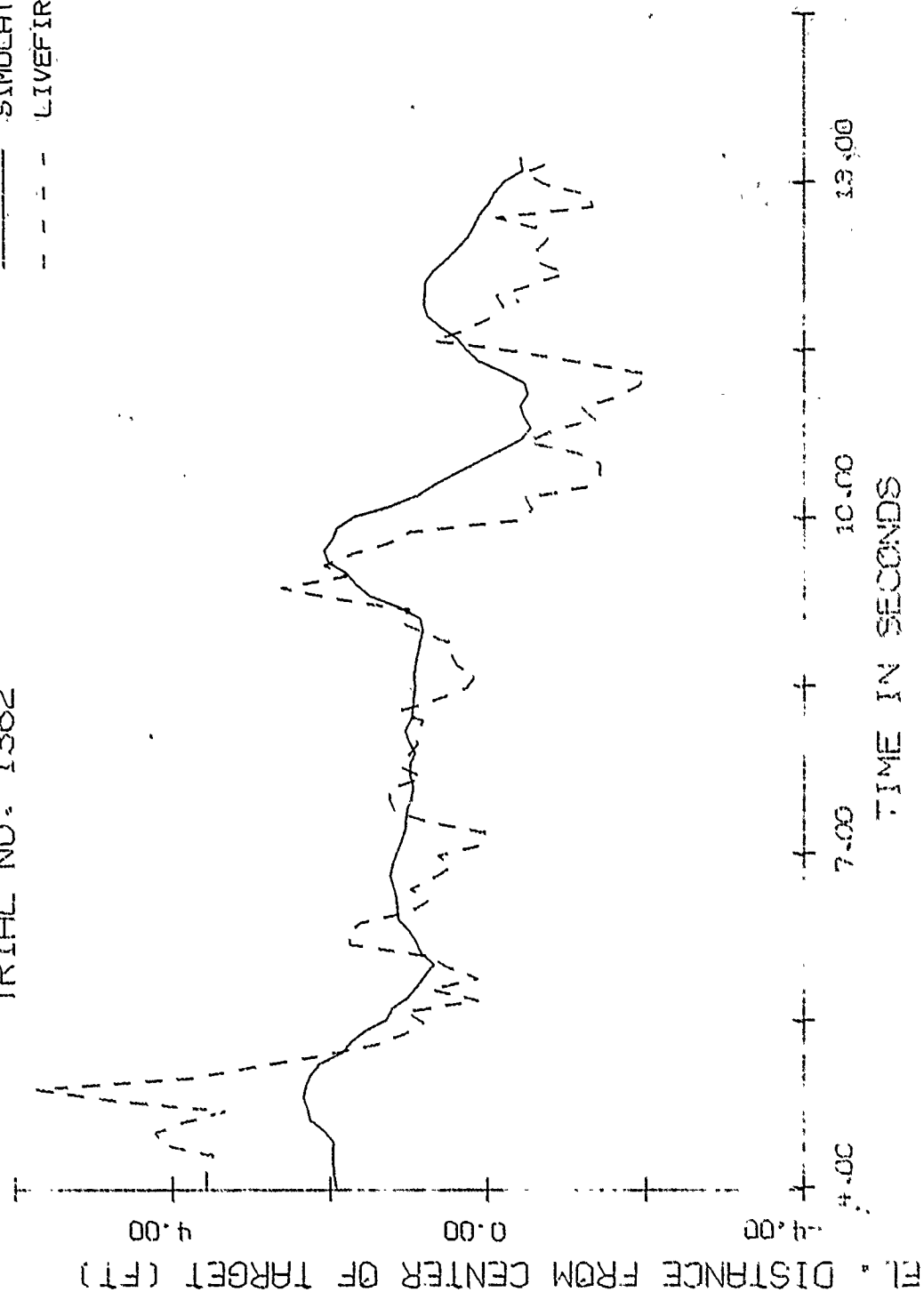
— SIMULATION
- - - LIVEFIRE

AZ, DISTANCE FROM CENTER OF TARGET (FT)



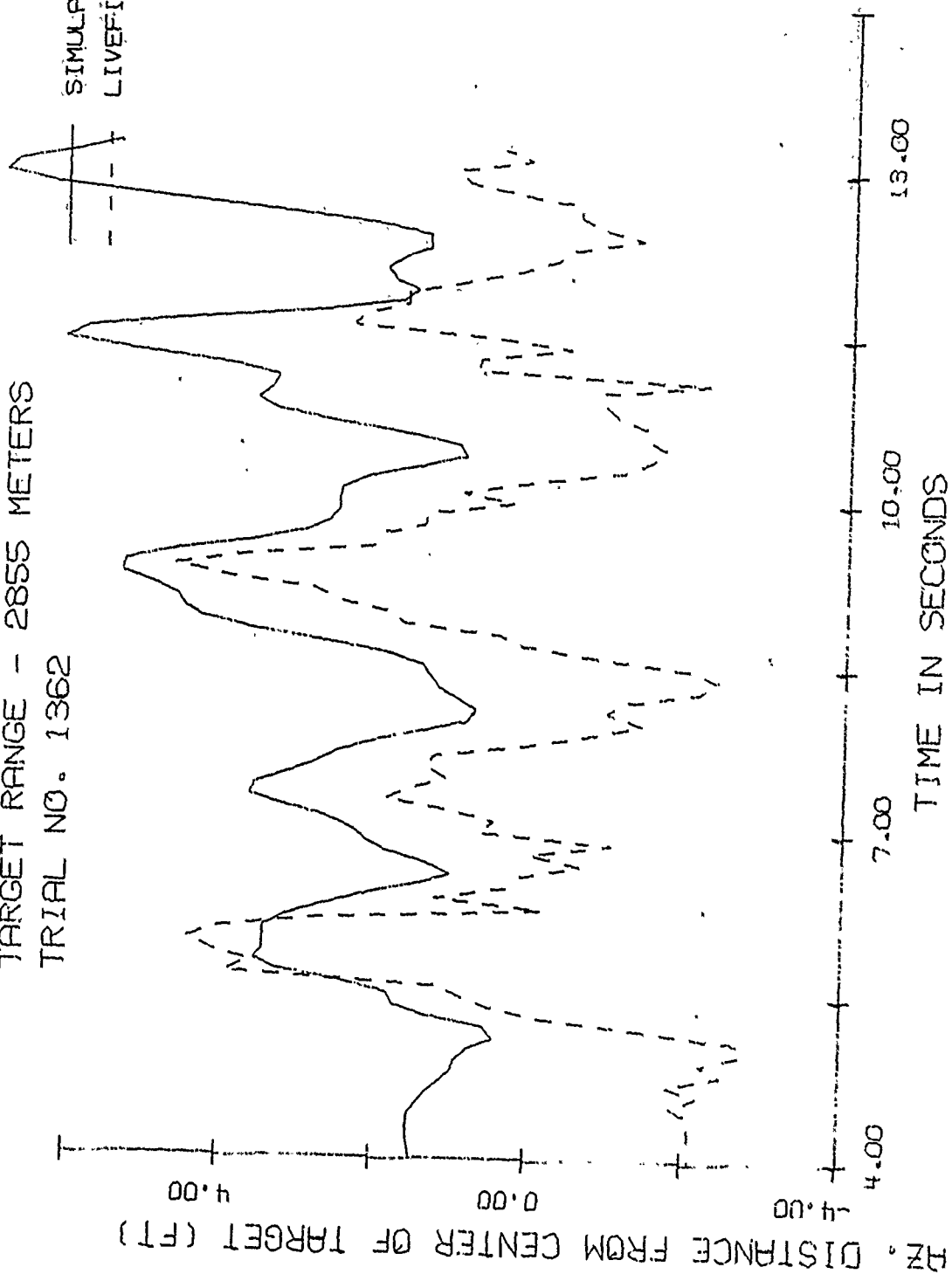
TARGET RANGE - 2855 METERS
 TRIAL NO. 1362

— SIMULATION
 - - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1362

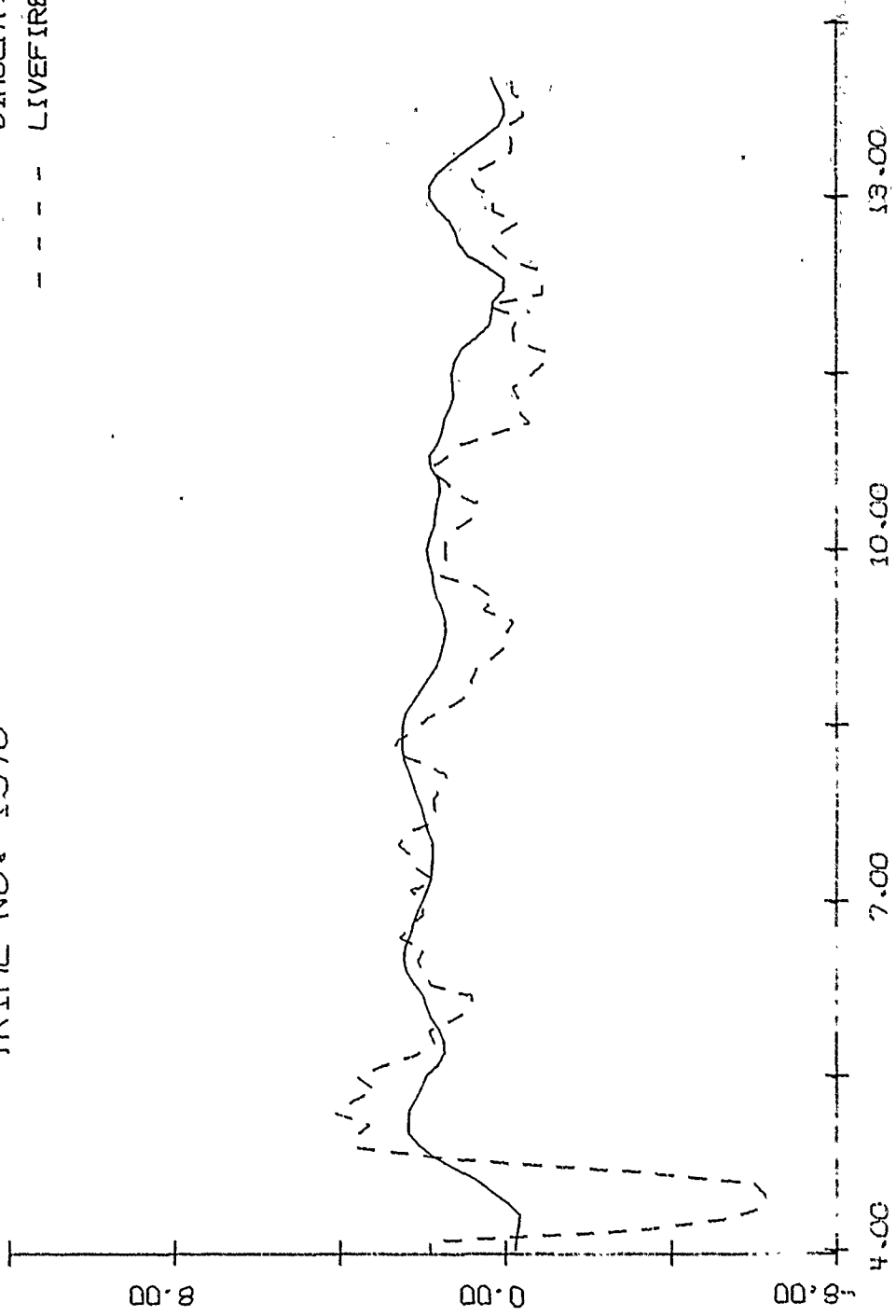
SIMULATION
LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 1370

— SIMULATION
- - - LIVEFIRE

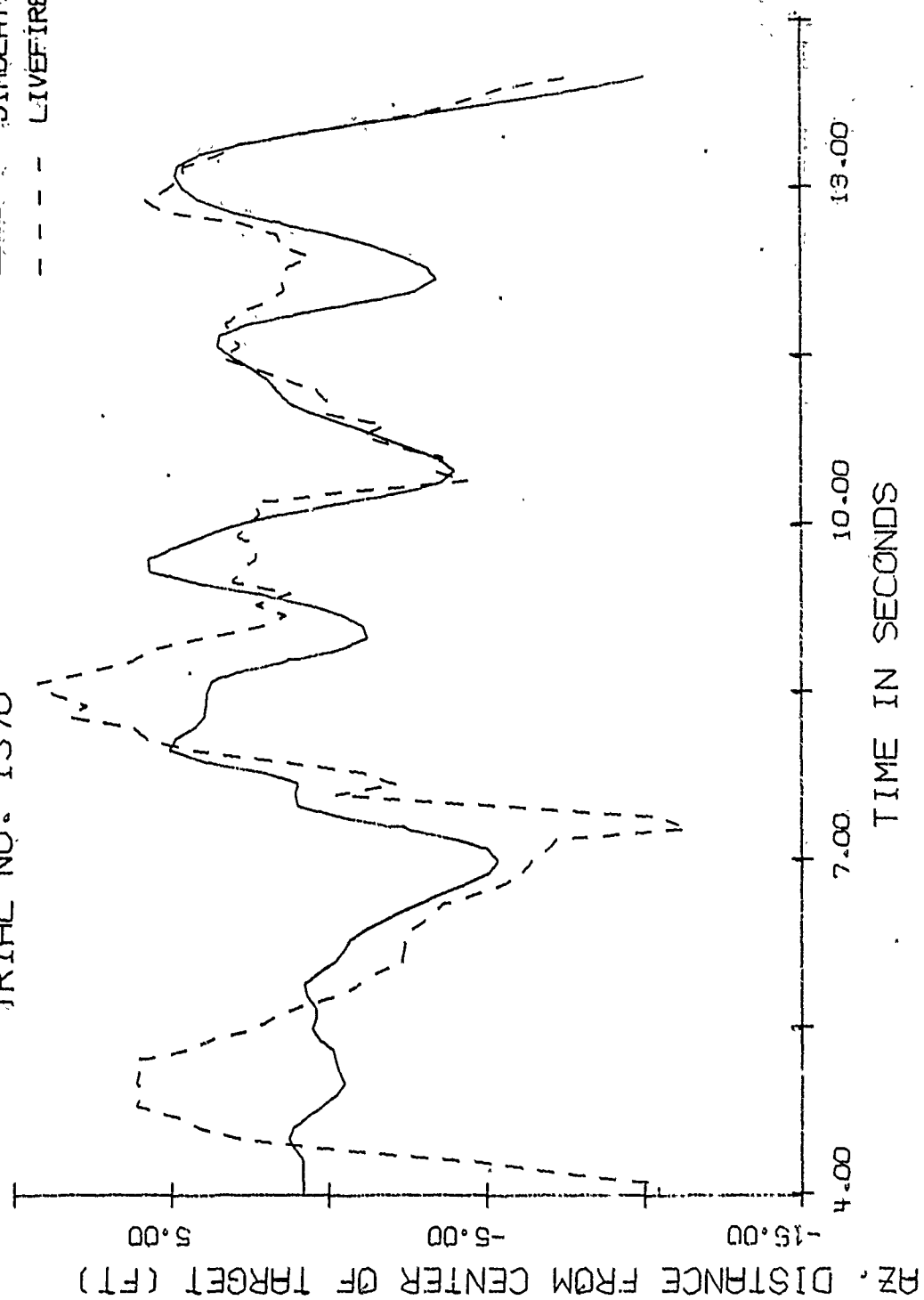
FL. DISTANCE FROM CENTER OF TARGET (FT)



TIME IN SECONDS

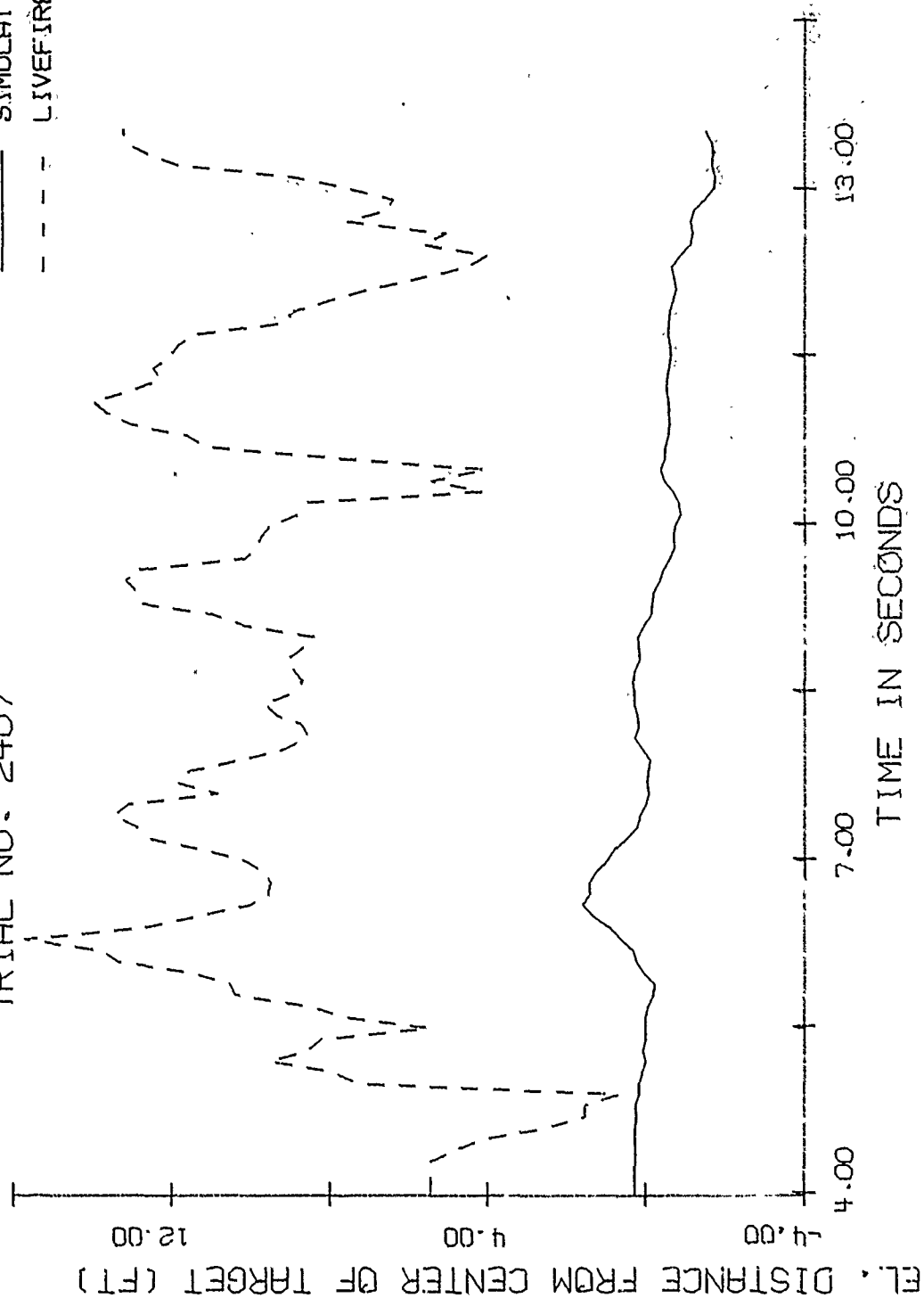
TARGET RANGE - 2855 METERS
TRIAL NO. 1370

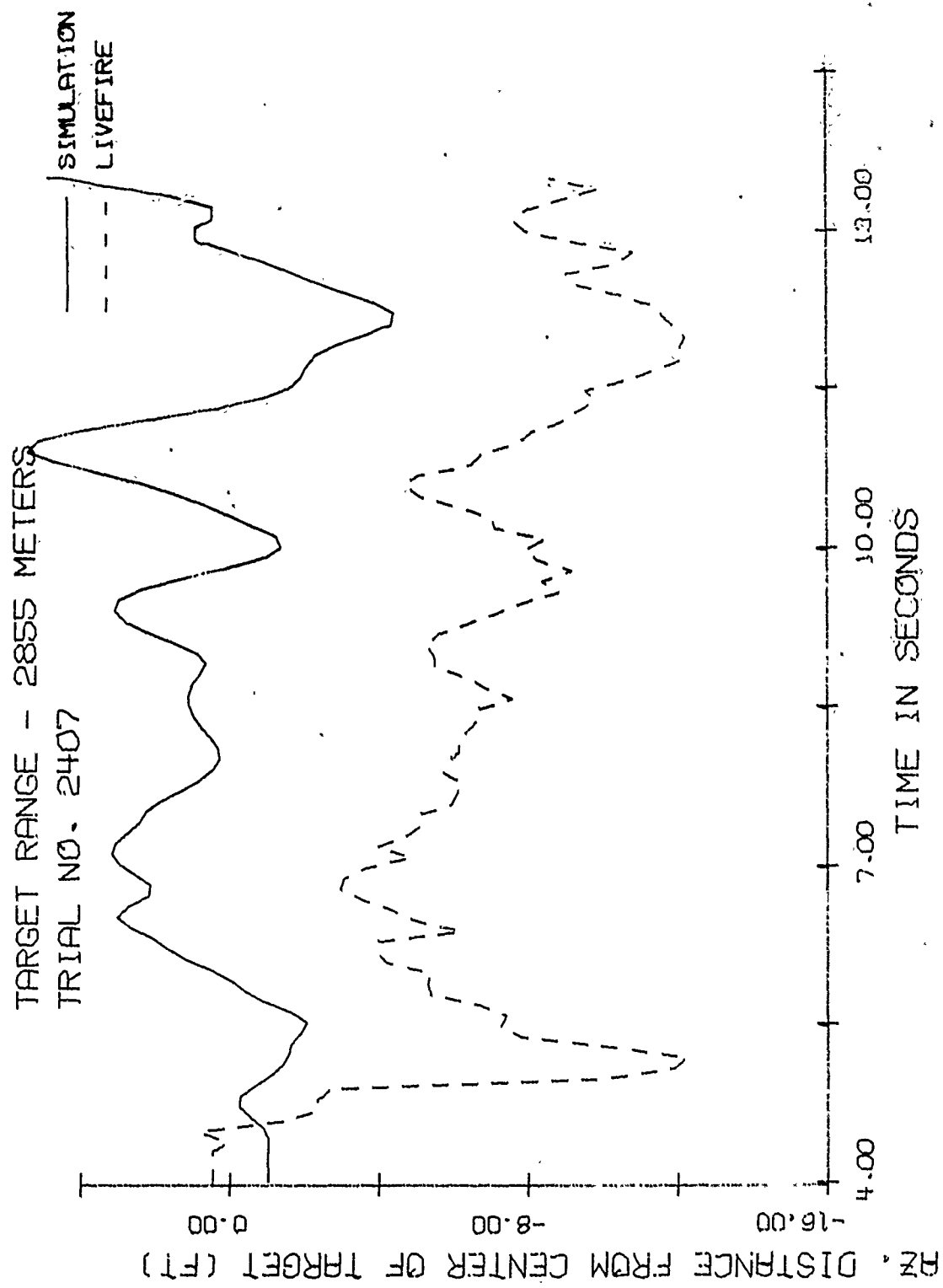
— SIMULATION
--- LIVEFIRE



TARGET RANGE - 2855 METERS
 TRIAL NO. 2407

— SIMULATION
 - - - LIVEFIRE

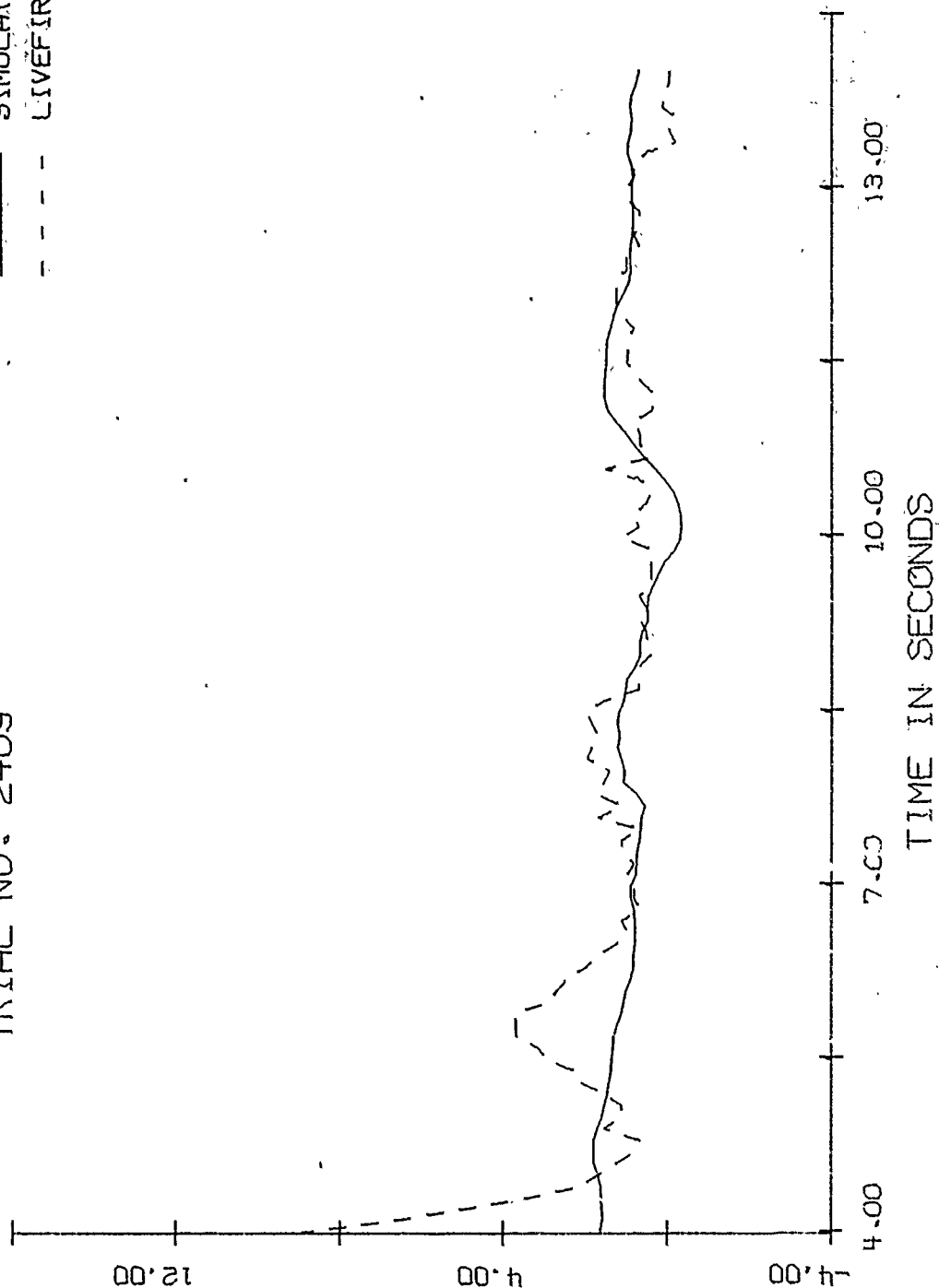




TARGET RANGE - 2855 METERS
TRIAL NO. 2409

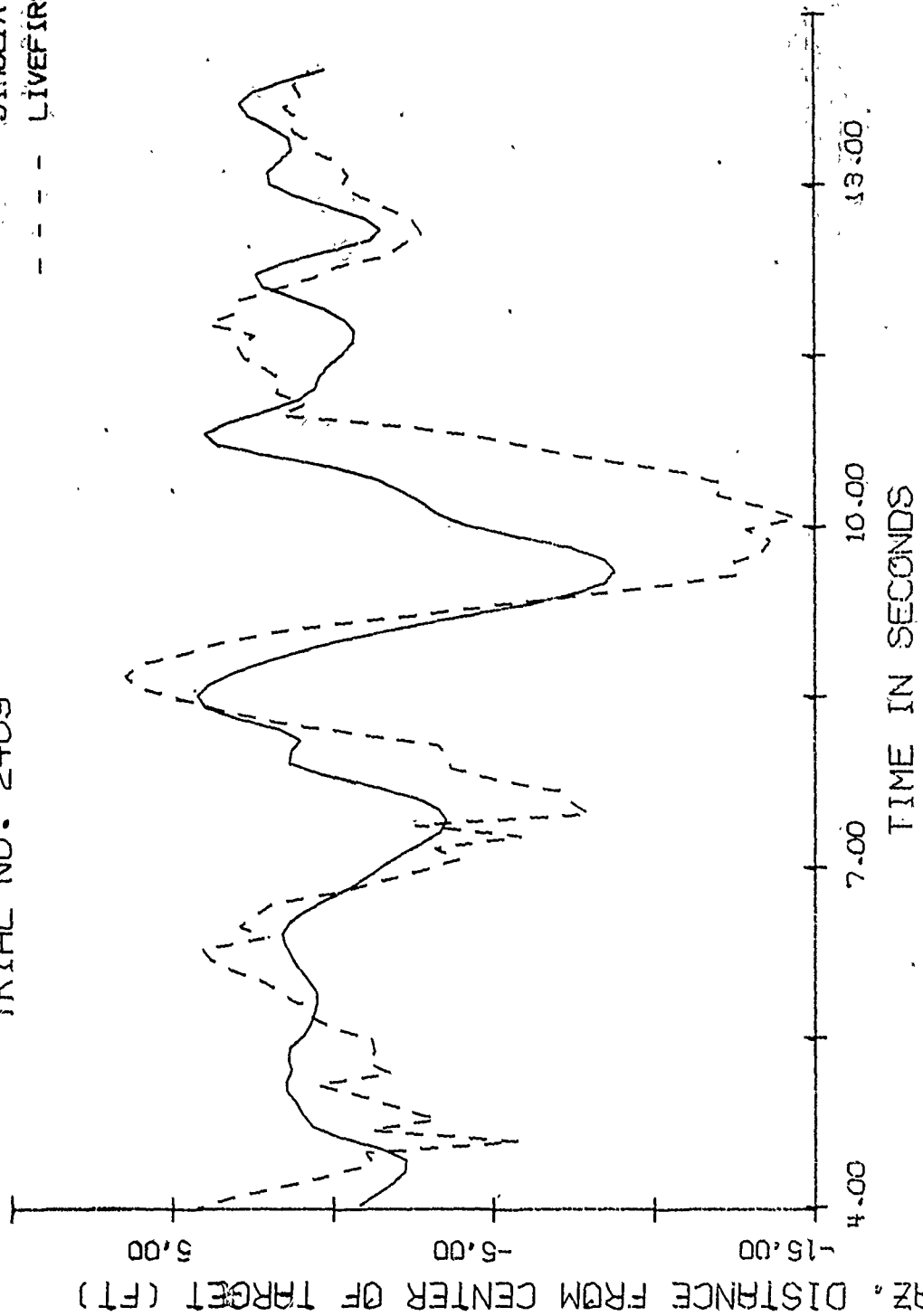
— SIMULATION
- - - LIVEFIRE

EL. DISTANCE FROM CENTER OF TARGET (FT)



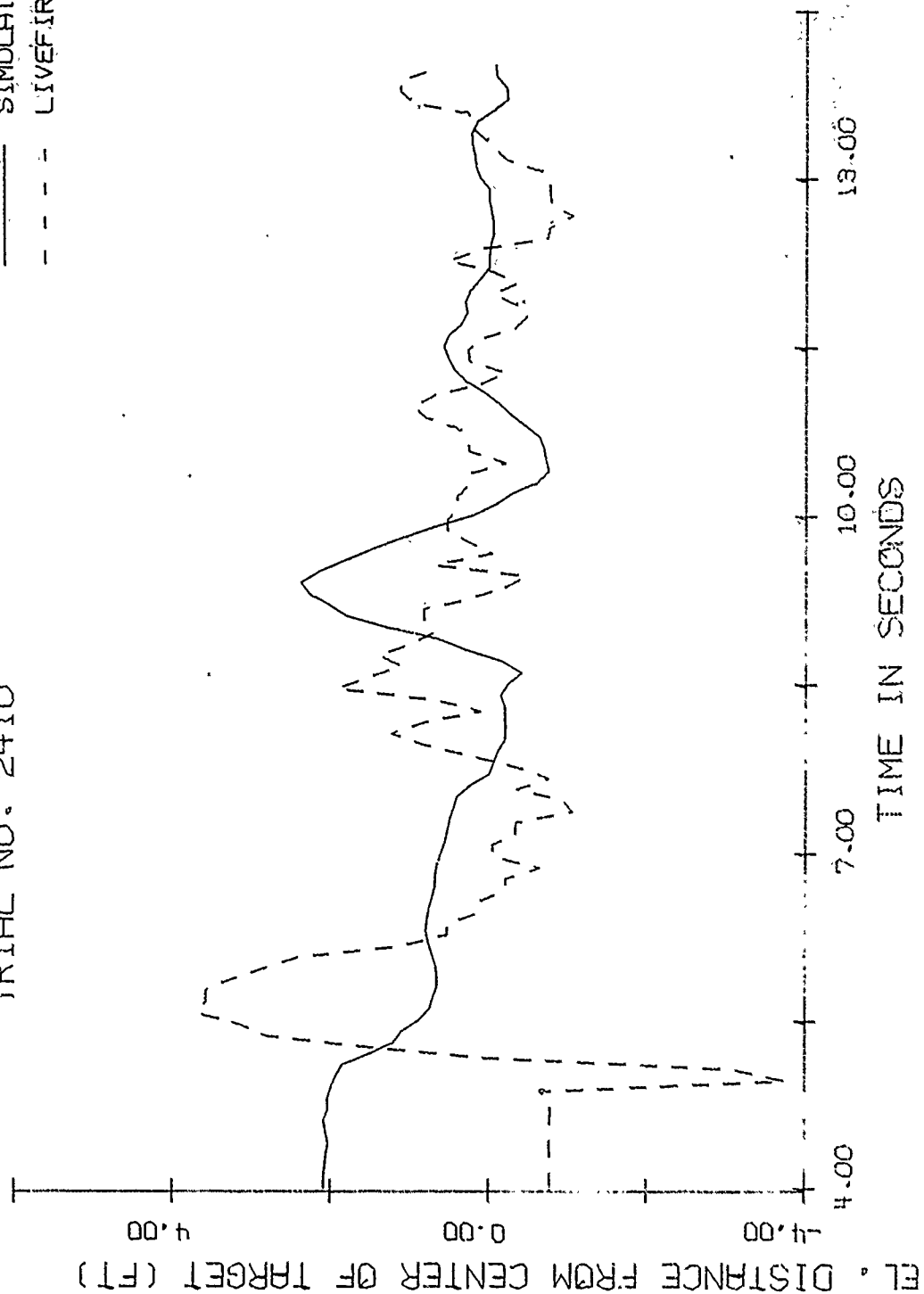
TARGET RANGE - 2855 METERS
TRIAL NO. 2409

— SIMULATION
--- LIVEFIRE



TARGET RANGE - 2855 METERS
 TRIAL NO. 2410

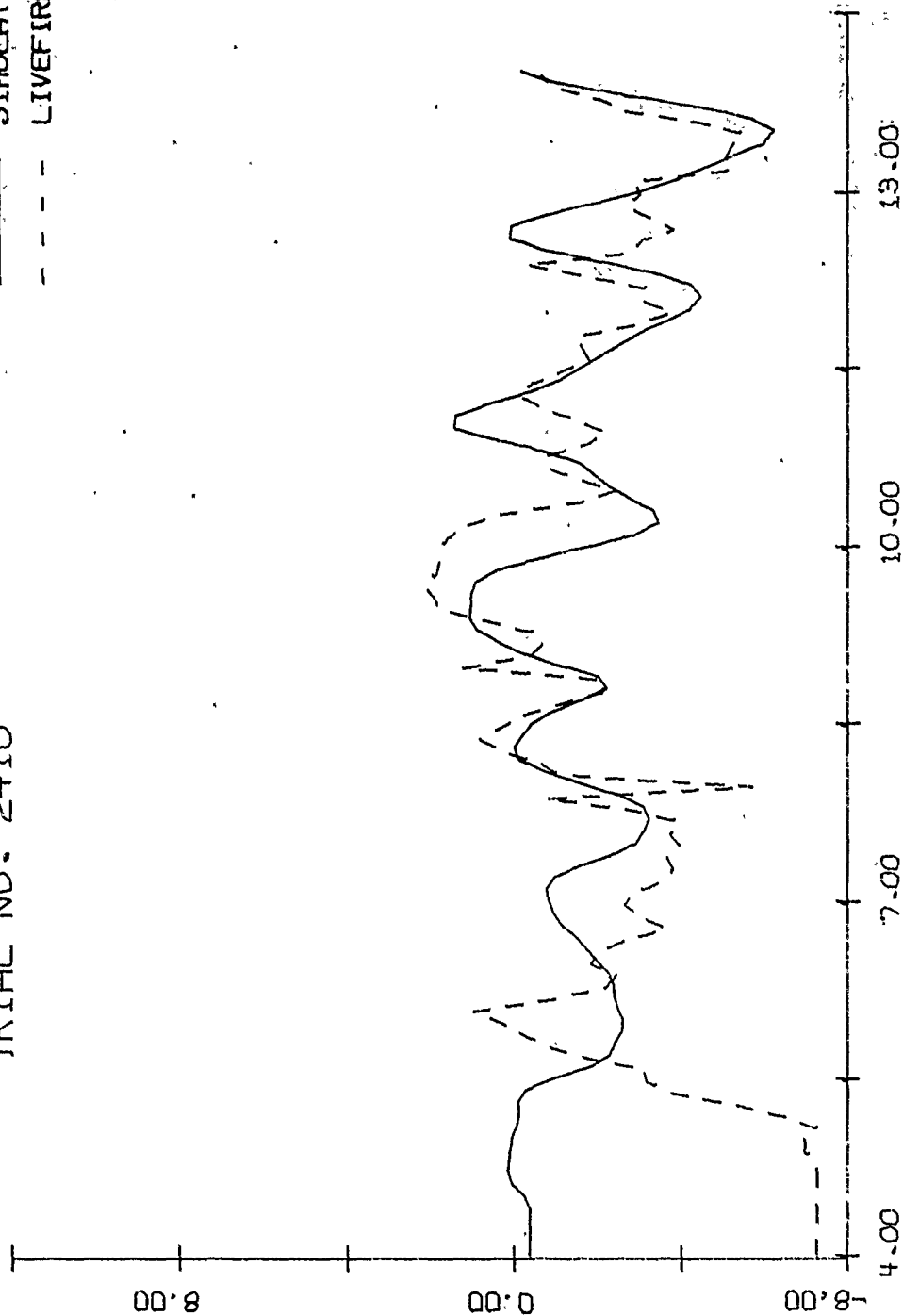
— SIMULATION
 - - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 2410

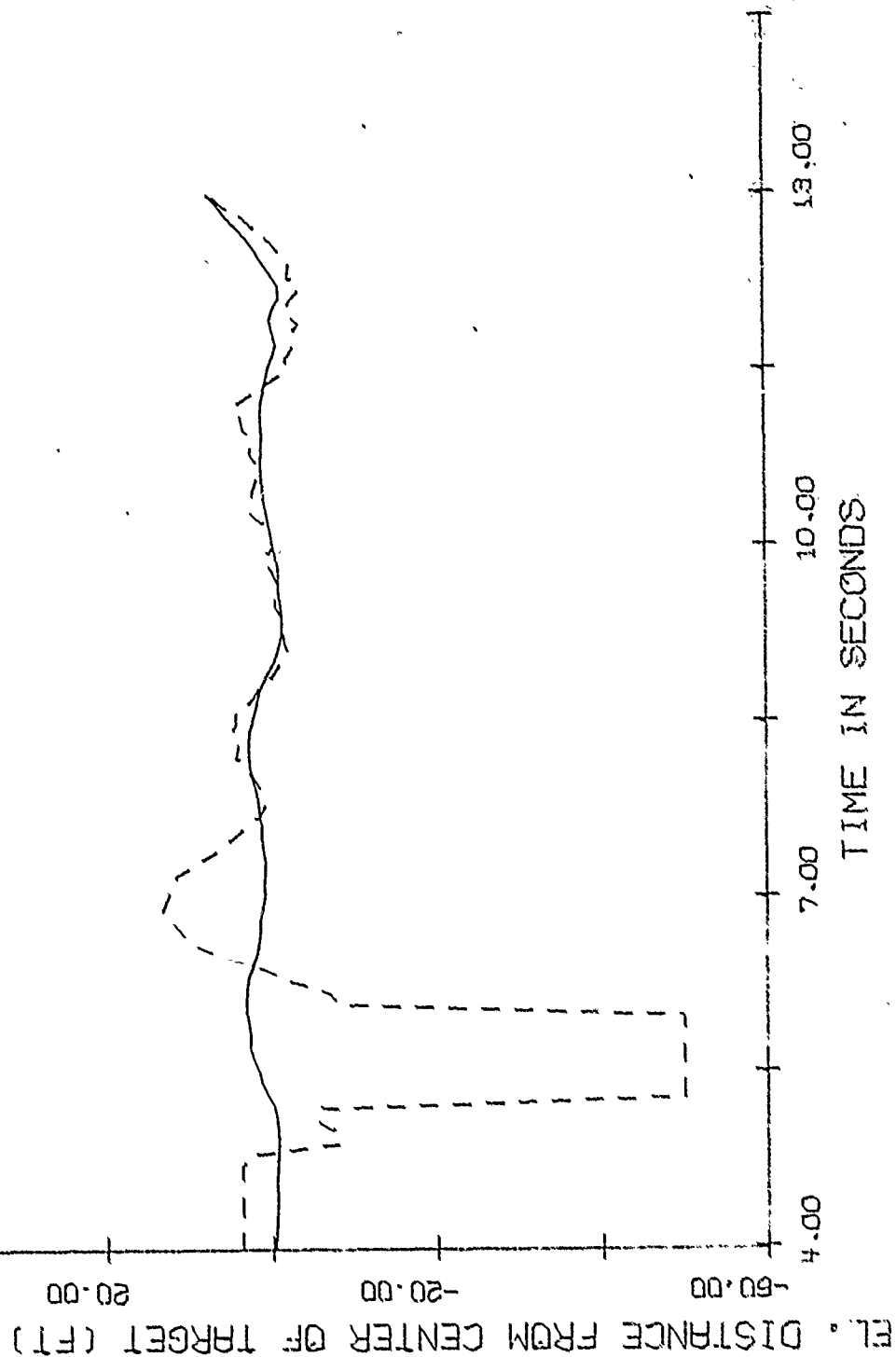
— SIMULATION
- - - LIVEFIRE

AZ. DISTANCE FROM CENTER OF TARGET (FT)



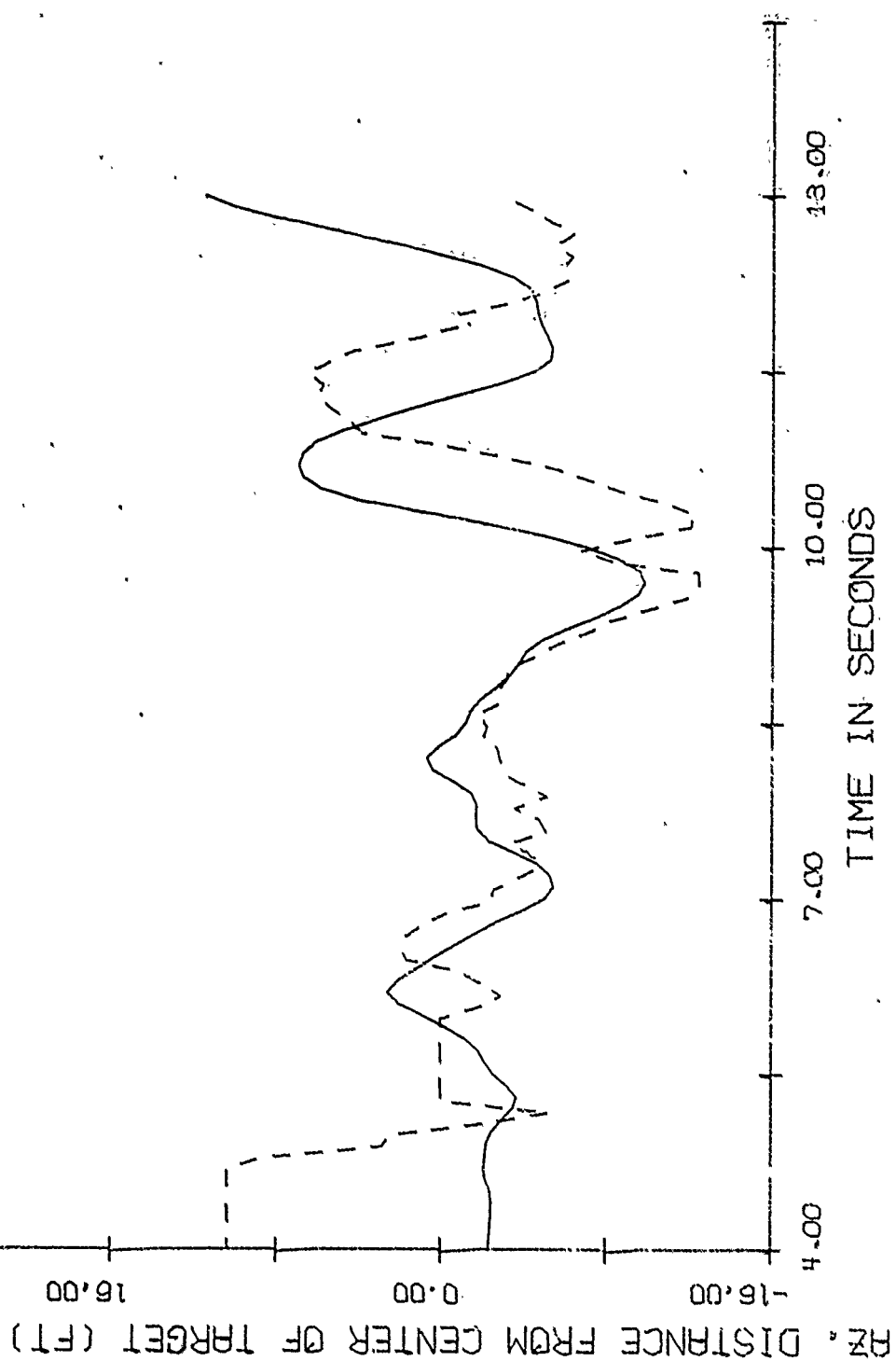
TARGET RANGE - 2855 METERS
TRIAL NO. 2412

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 2412

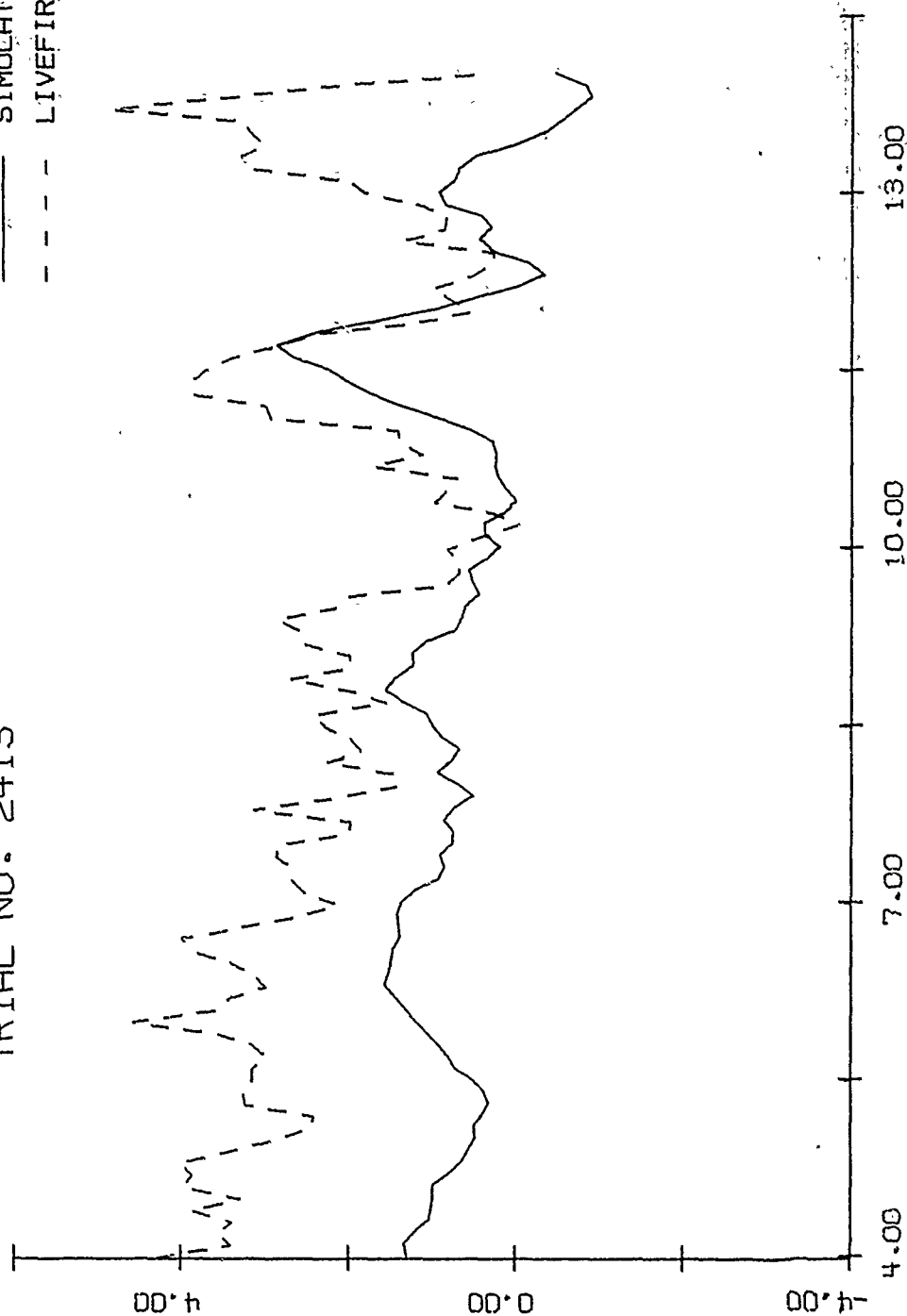
— SIMULATION
- - - LIVE FIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 2413

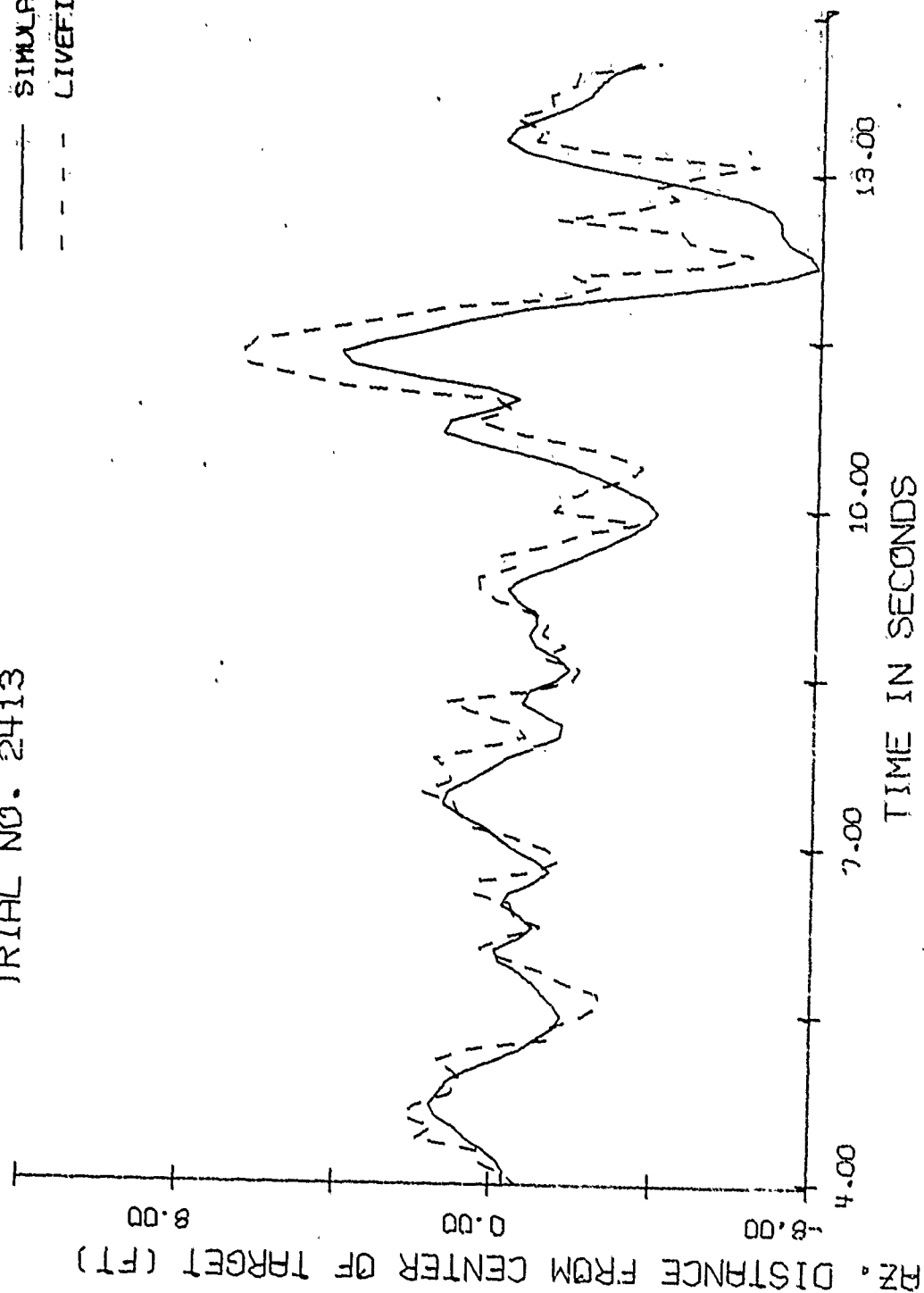
— SIMULATION
- - - LIVEFIRE

FL. DISTANCE FROM CENTER OF TARGET (FT)



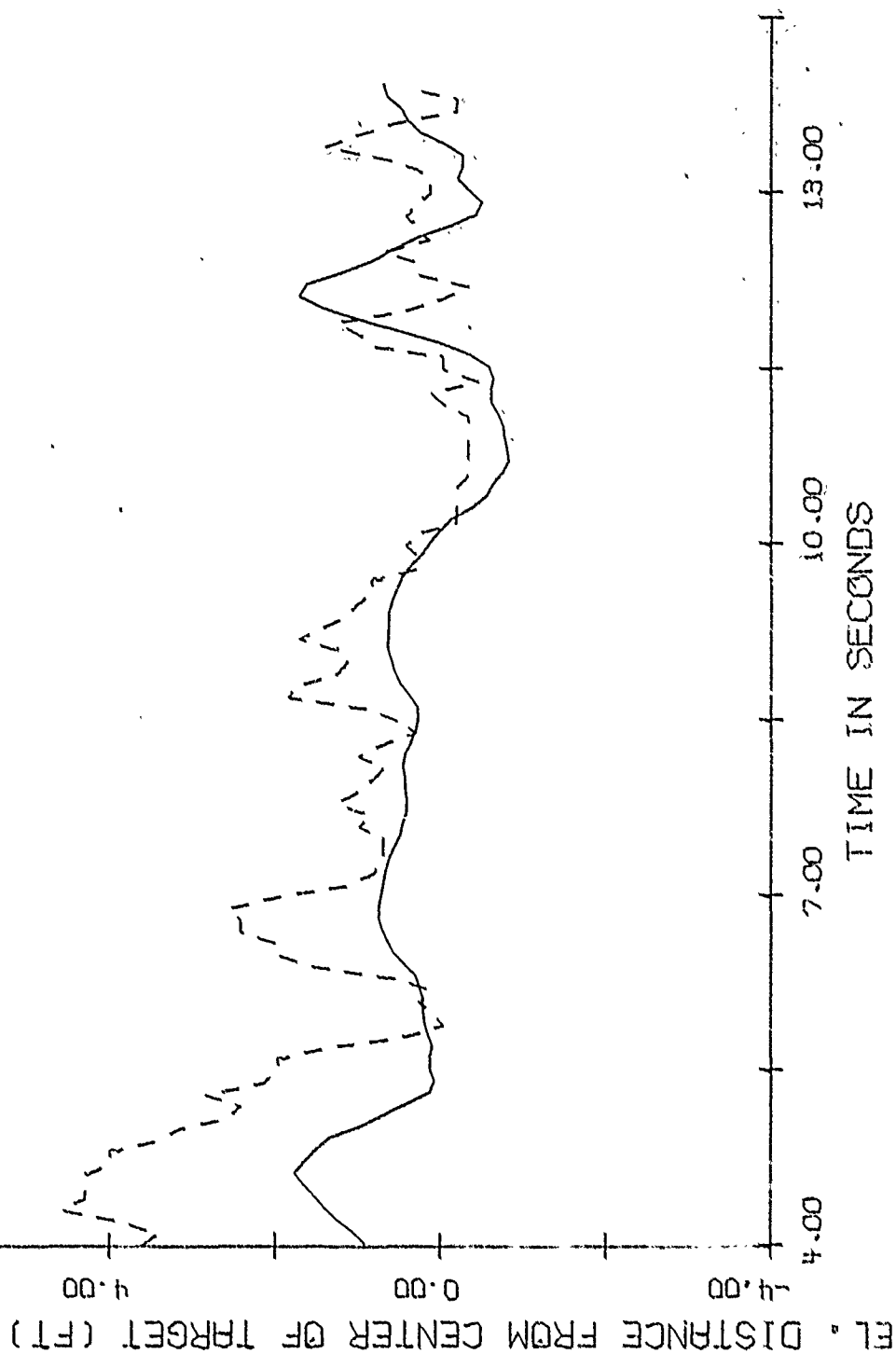
TARGET RANGE - 2855 METERS
TRIAL NO. 2413

— SIMULATION
- - - LIVEFIRE



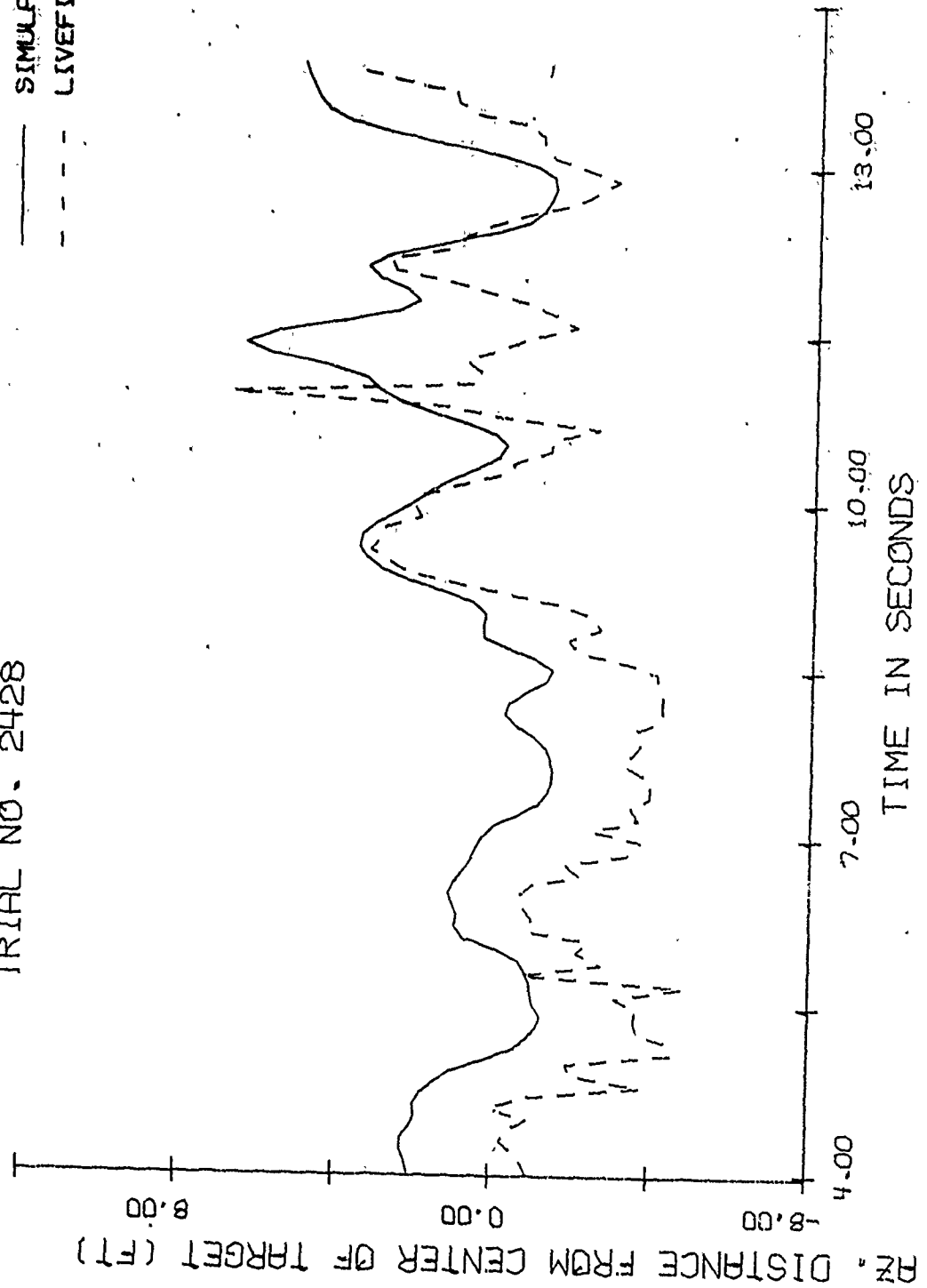
TARGET RANGE - 2855 METERS
TRIAL NO. 2428

— SIMULATION
- - - LIVEFIRE



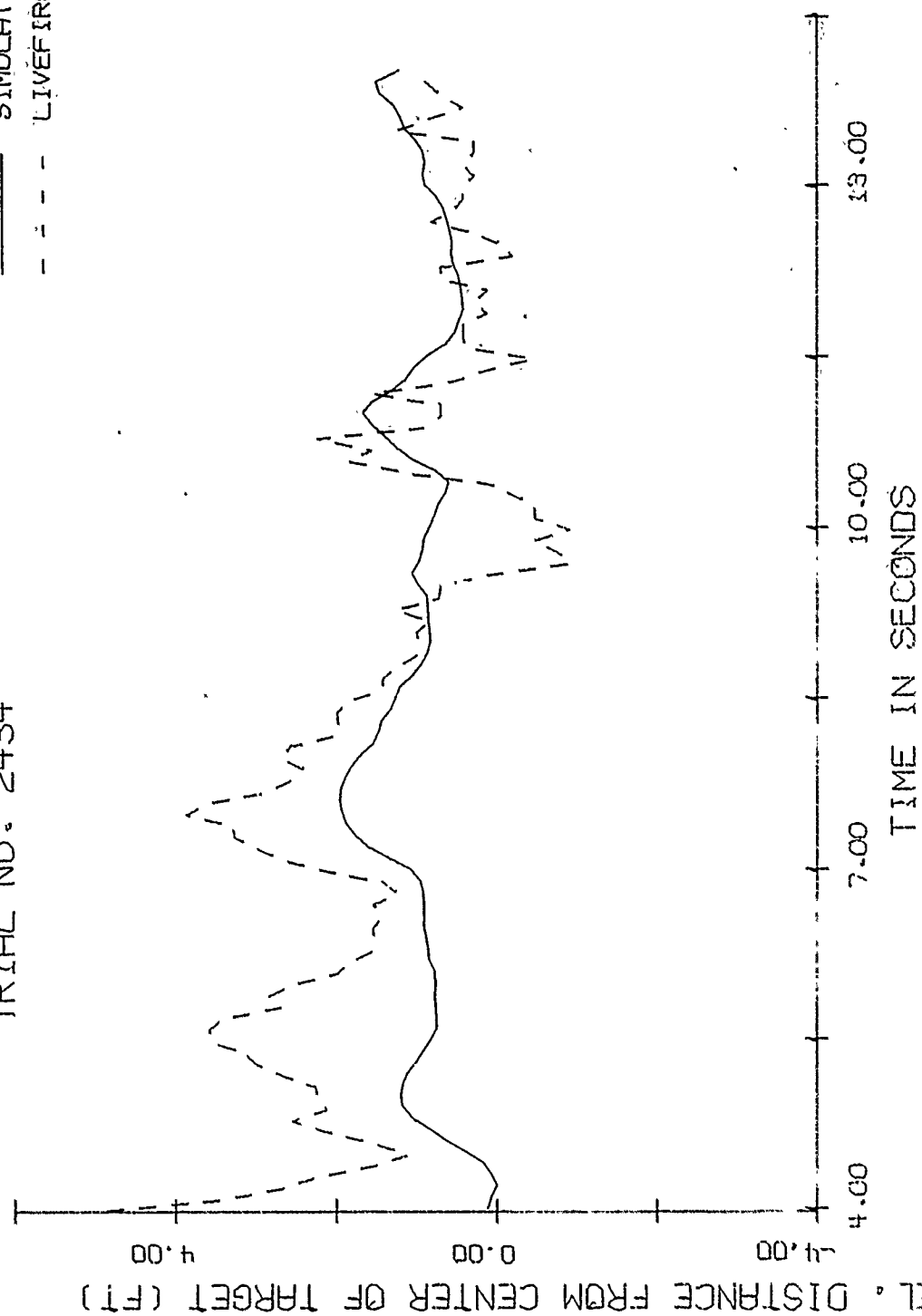
TARGET RANGE - 2855 METERS
TRIAL NO. 2428

— SIMULATION
- - - LIVEFIRE

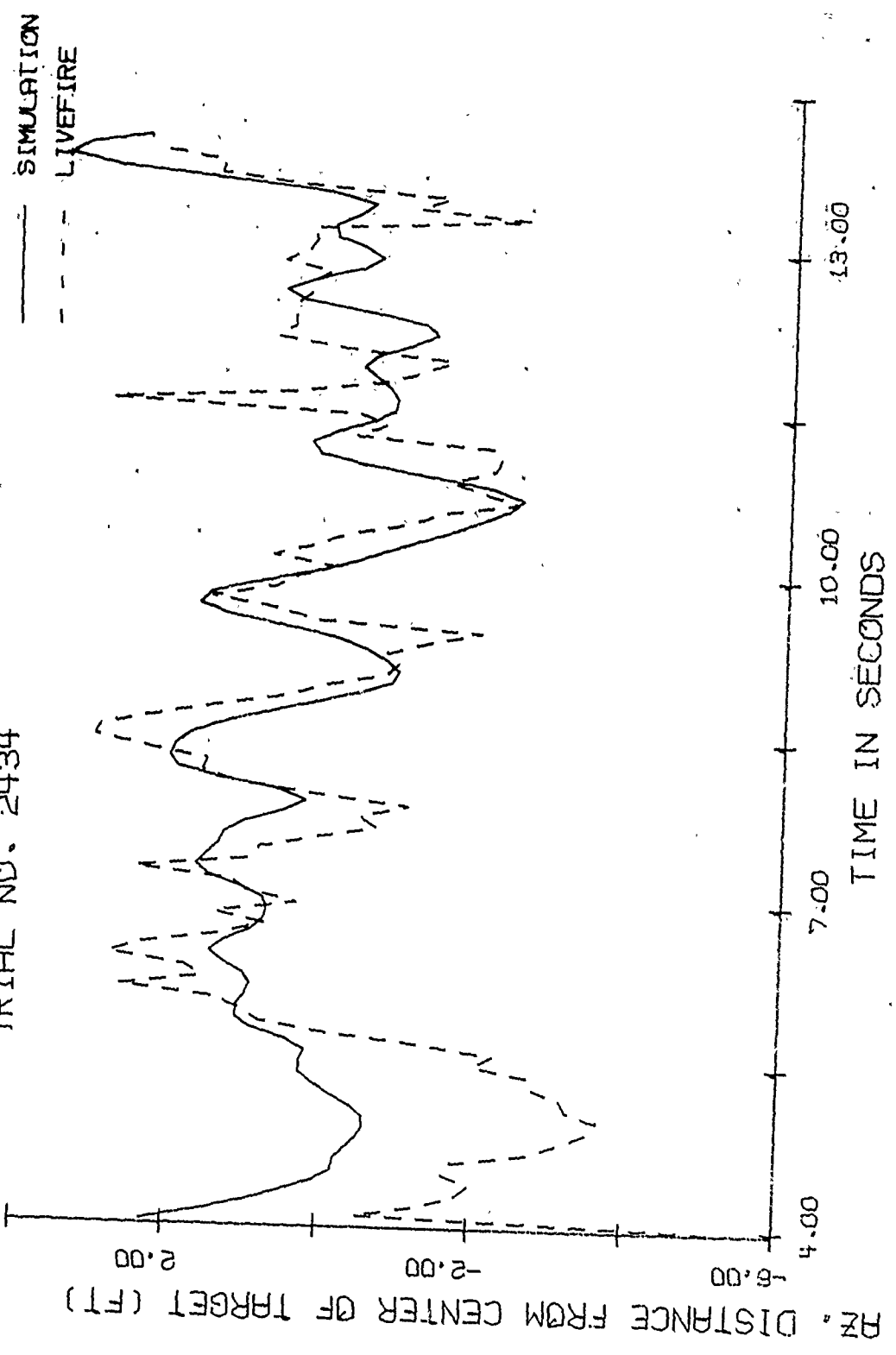


TARGET RANGE - 2855 METERS
TRIAL NO. 2434

— SIMULATION
- - - LIVEFIRE

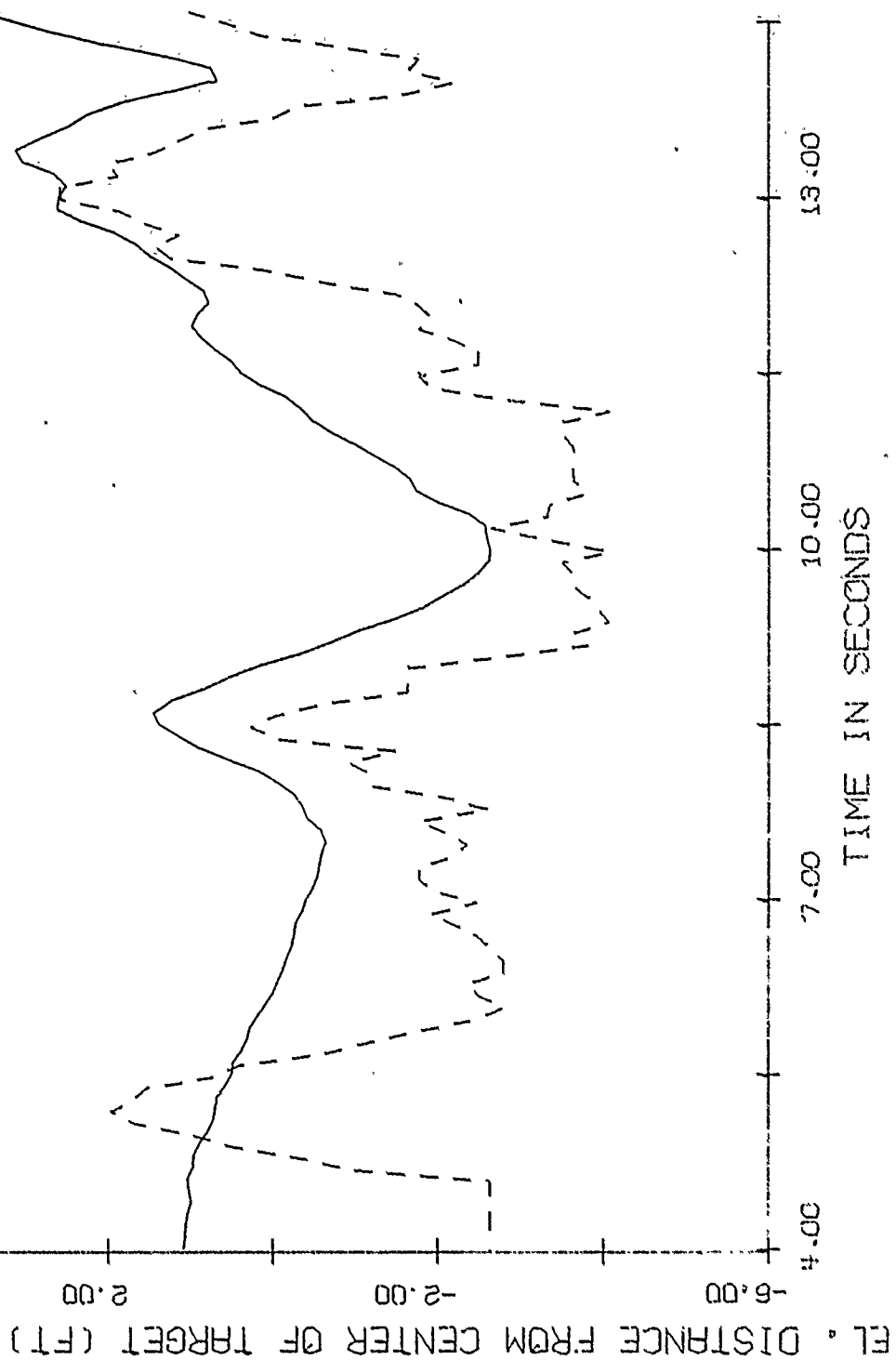


TARGET RANGE - 2855 METERS
TRIAL NO. 2434



TARGET RANGE - 2855 METERS
TRIAL NO. 2435

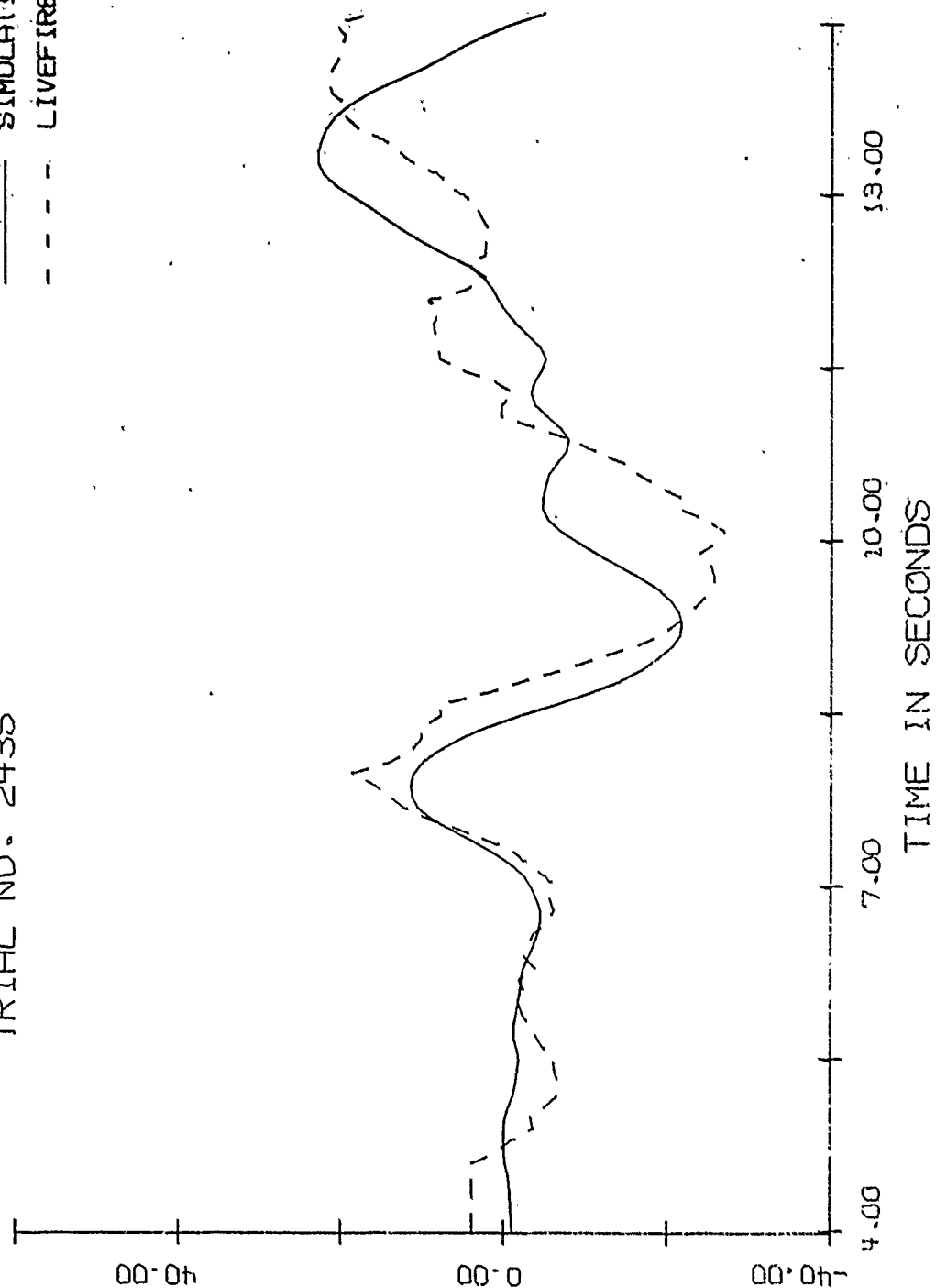
— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 2435

— SIMULATION
- - - LIVEFIRE

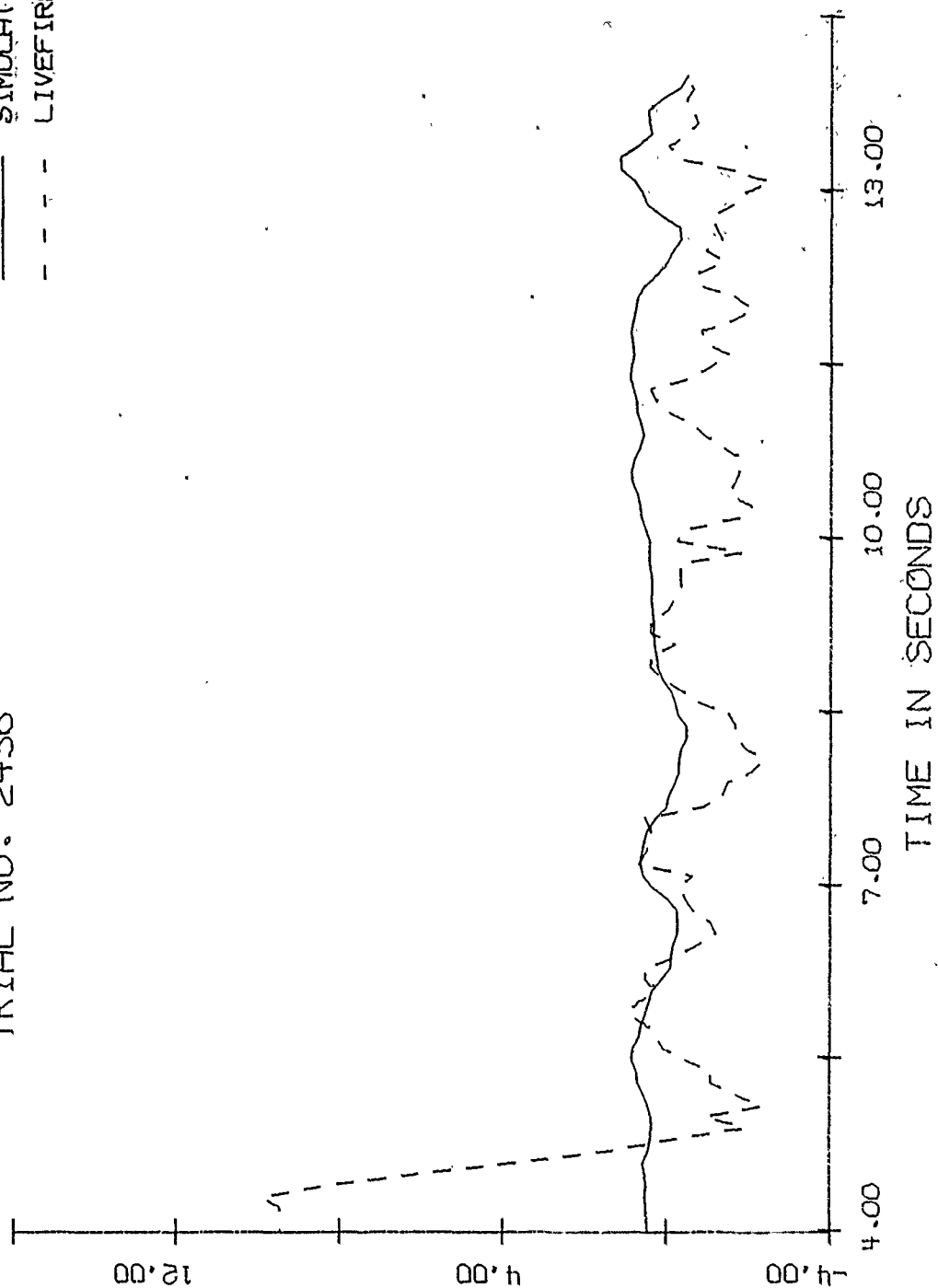
AZ. DISTANCE FROM CENTER OF TARGET (FT)



TARGET RANGE - 2855 METERS
TRIAL NO. 2436

— SIMULATION
- - - LIVEFIRE

EL. DISTANCE FROM CENTER OF TARGET (FT)

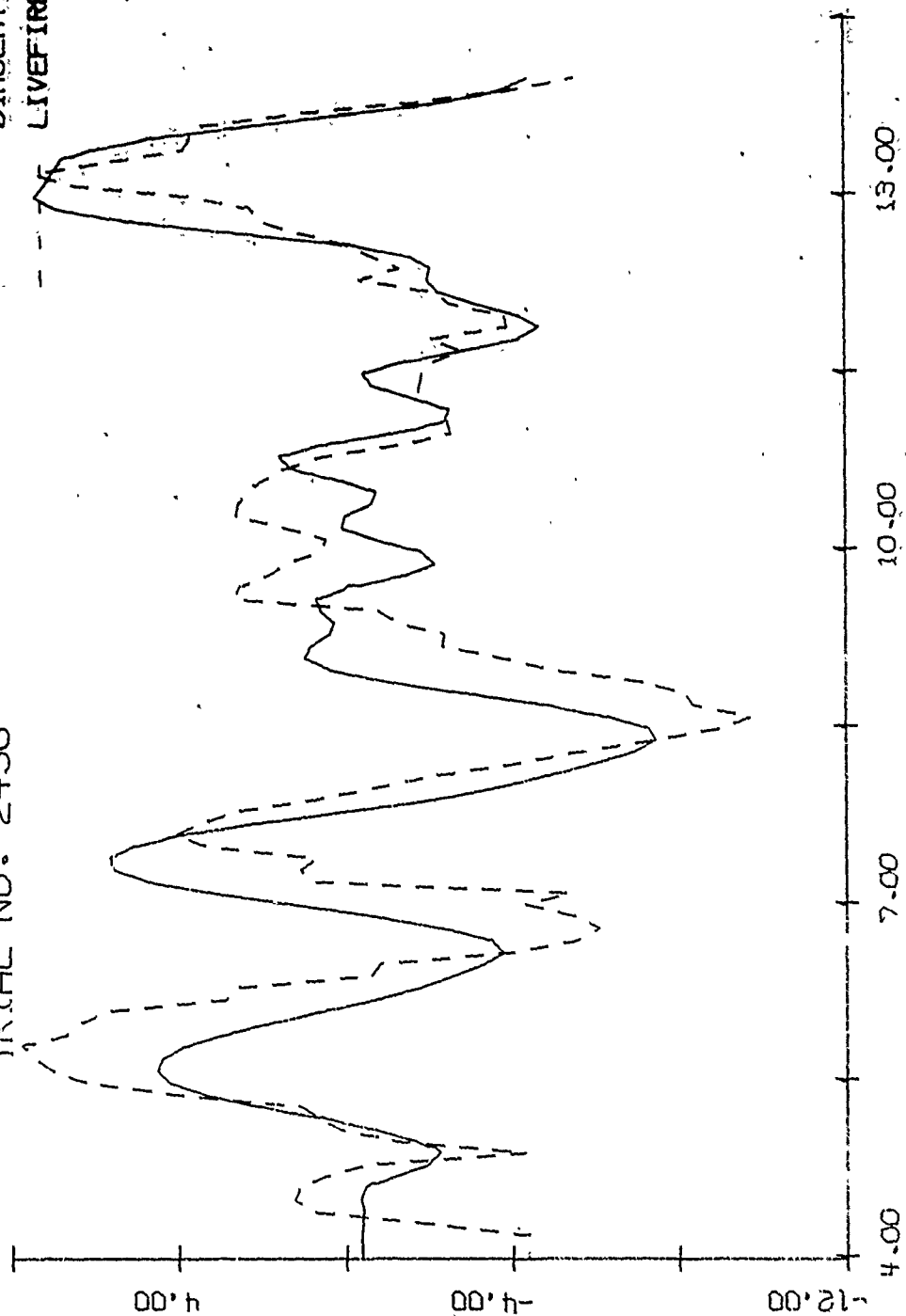


TARGET RANGE - 2855 METERS
TRIAL NO. 2436

SIMULATION
LIVEFIRE

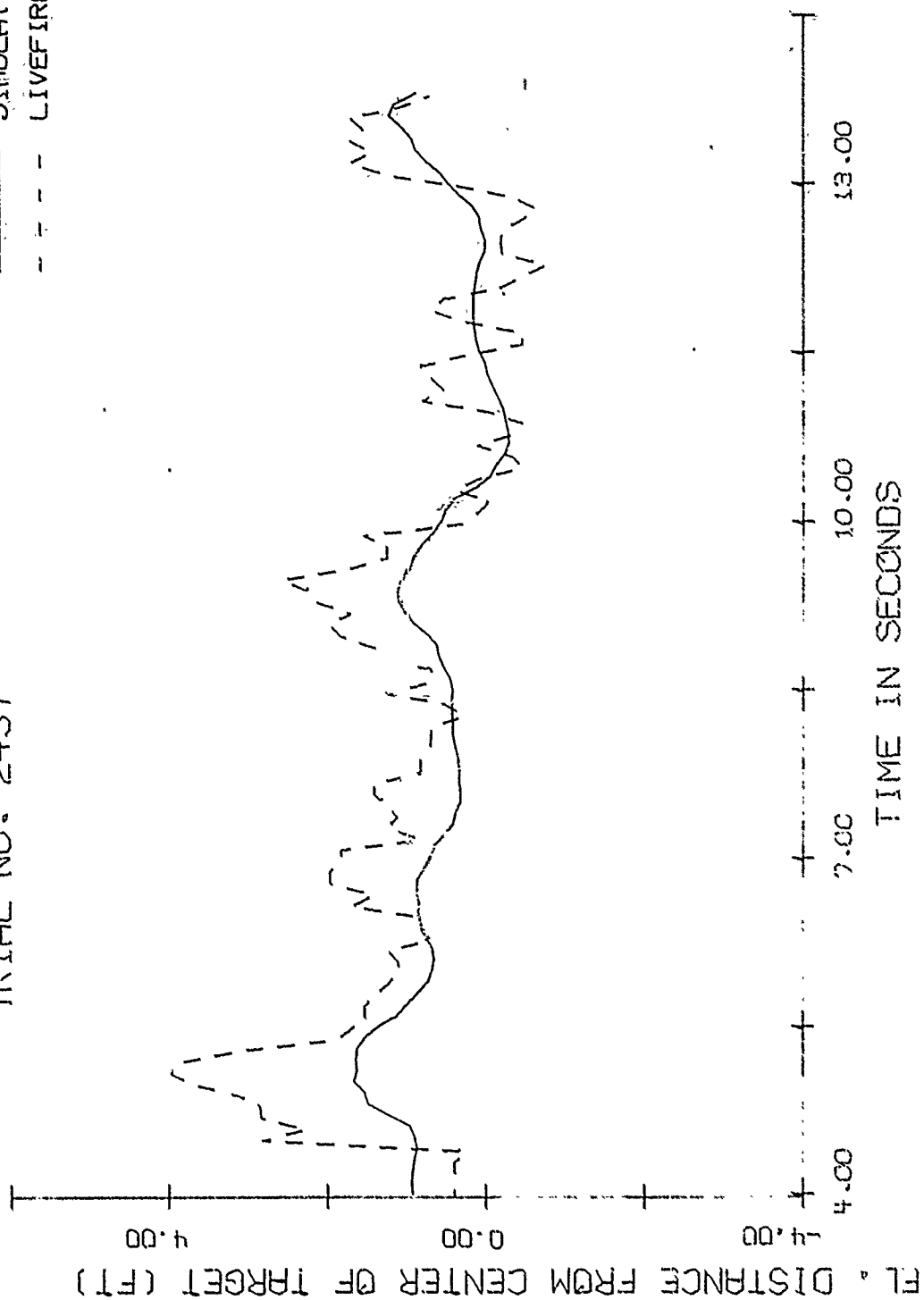
AZ, DISTANCE FROM CENTER OF TARGET (FT)

TIME IN SECONDS

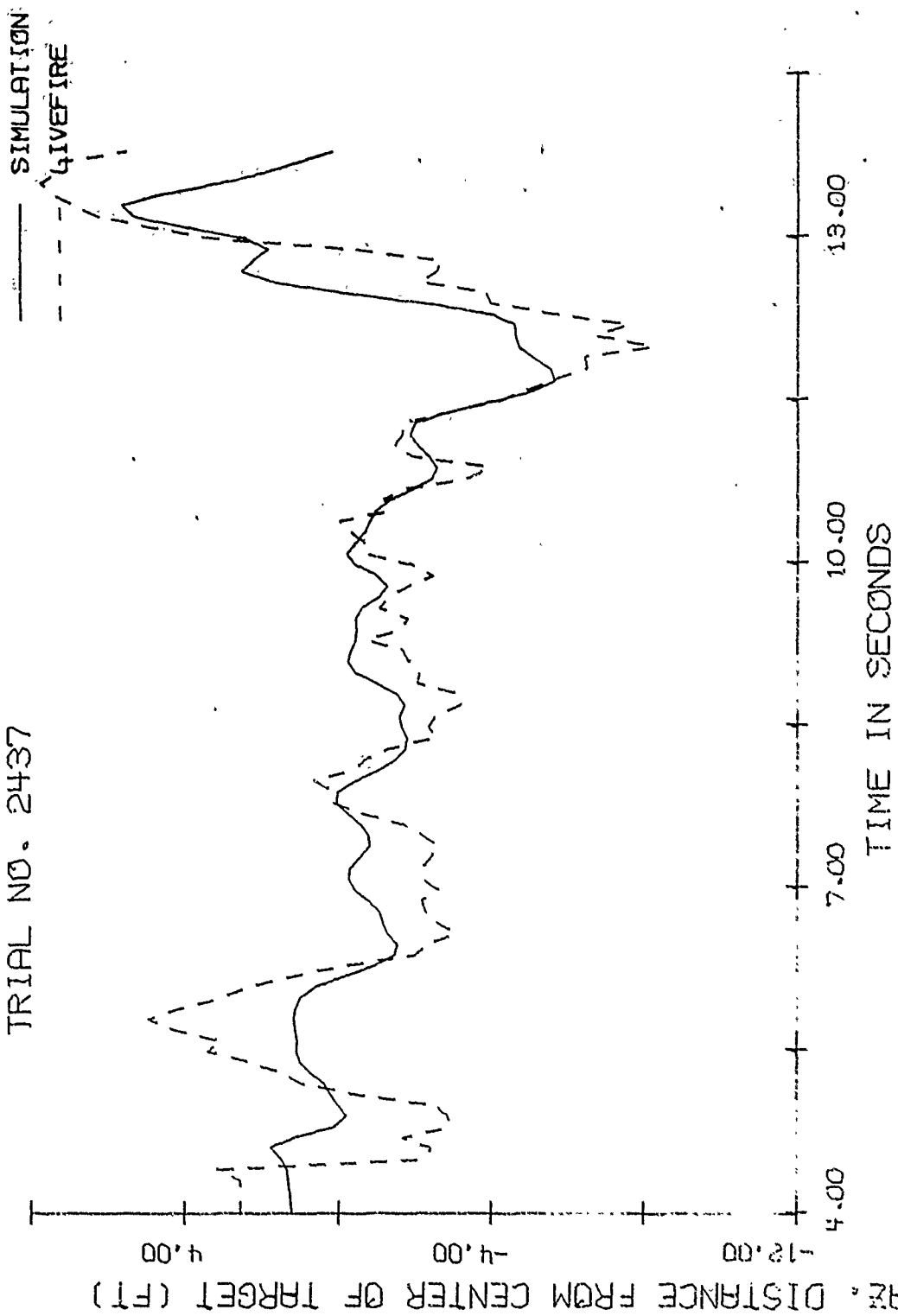


TARGET RANGE - 2855 METERS
TRIAL NO. 2437

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 2437

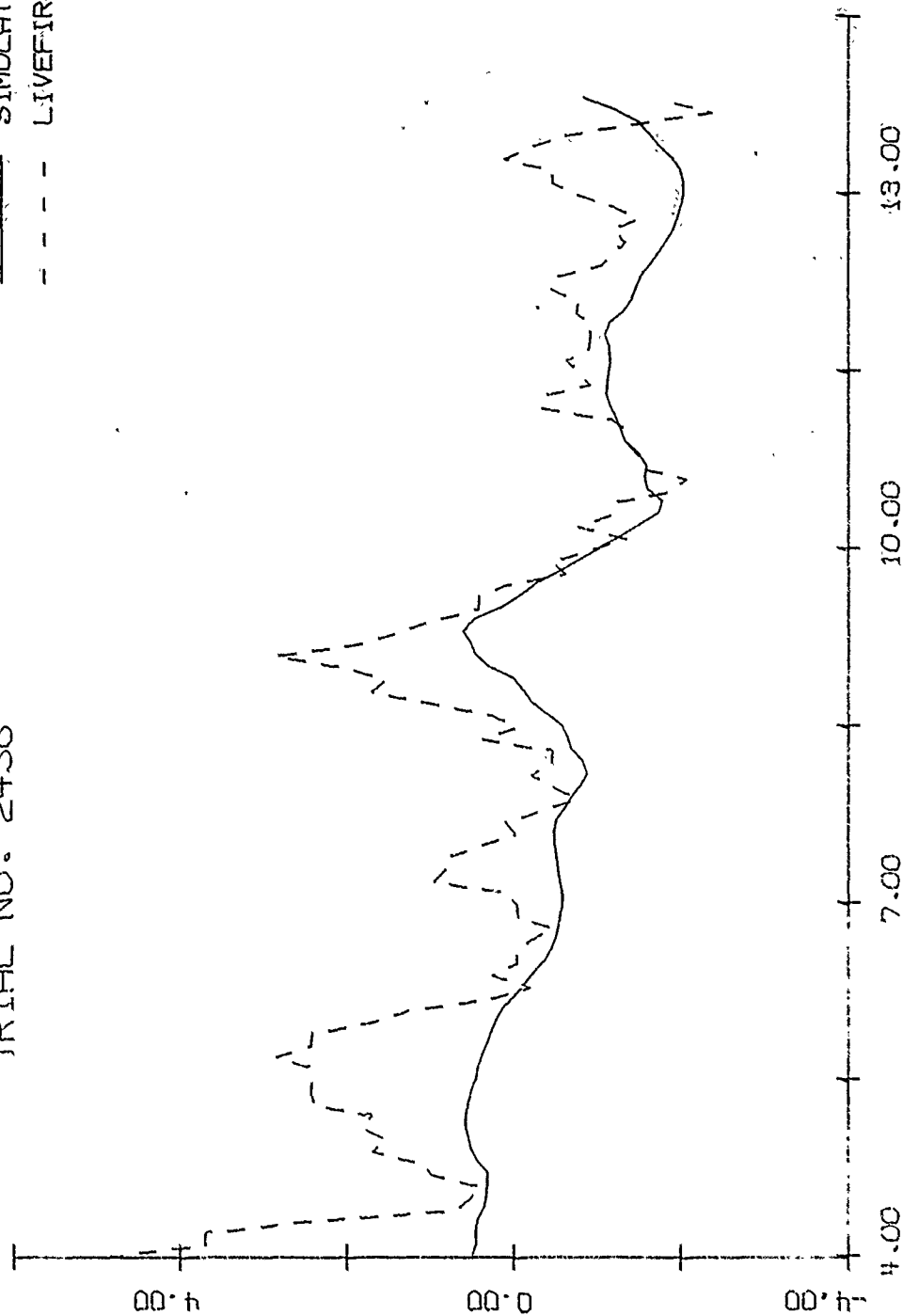


TARGET RANGE - 2855 METERS
TRIAL NO. 2438

— SIMULATION
- - - LIVEFIRE

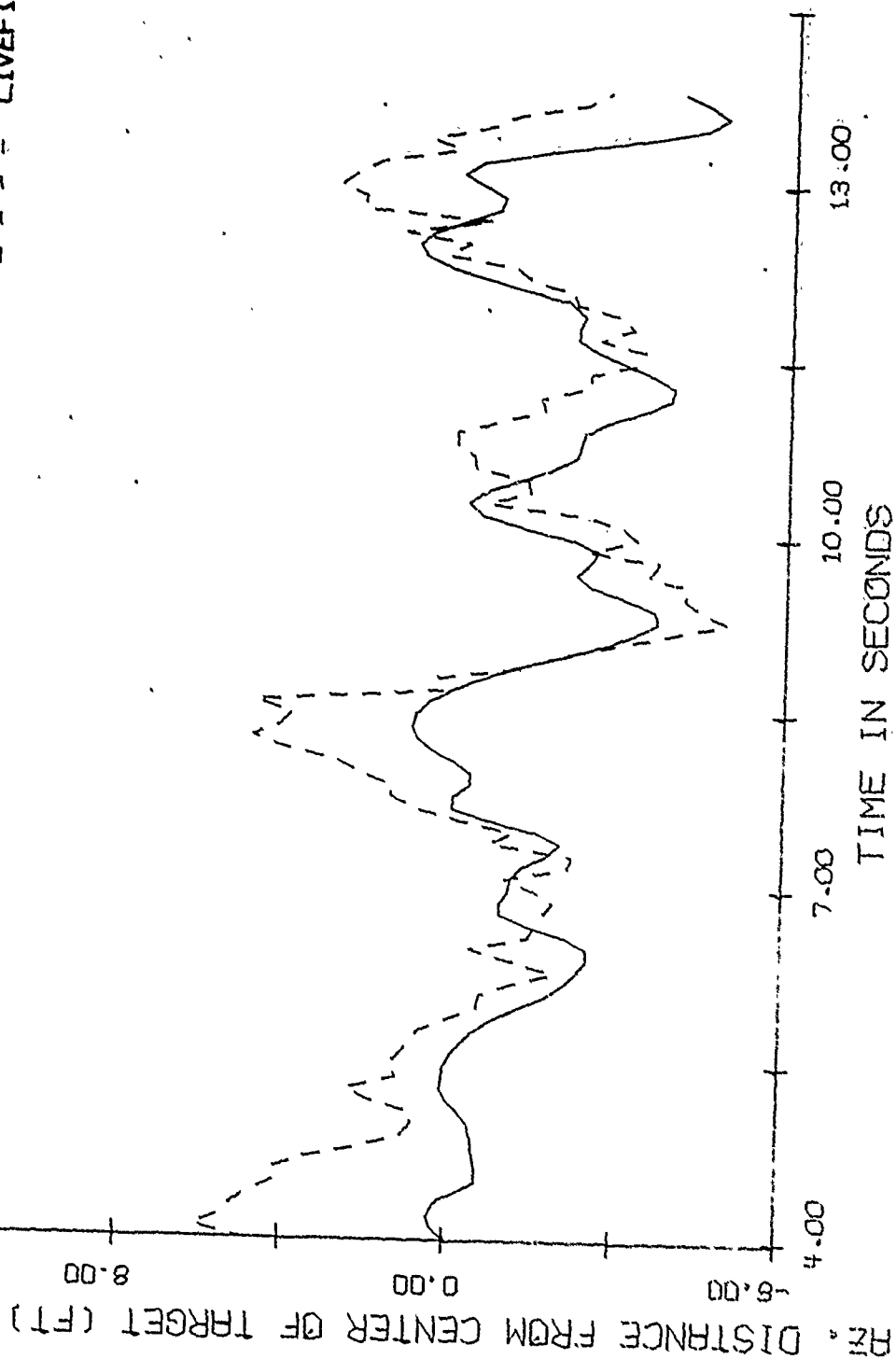
FL. DISTANCE FROM CENTER OF TARGET (FT)

TIME IN SECONDS



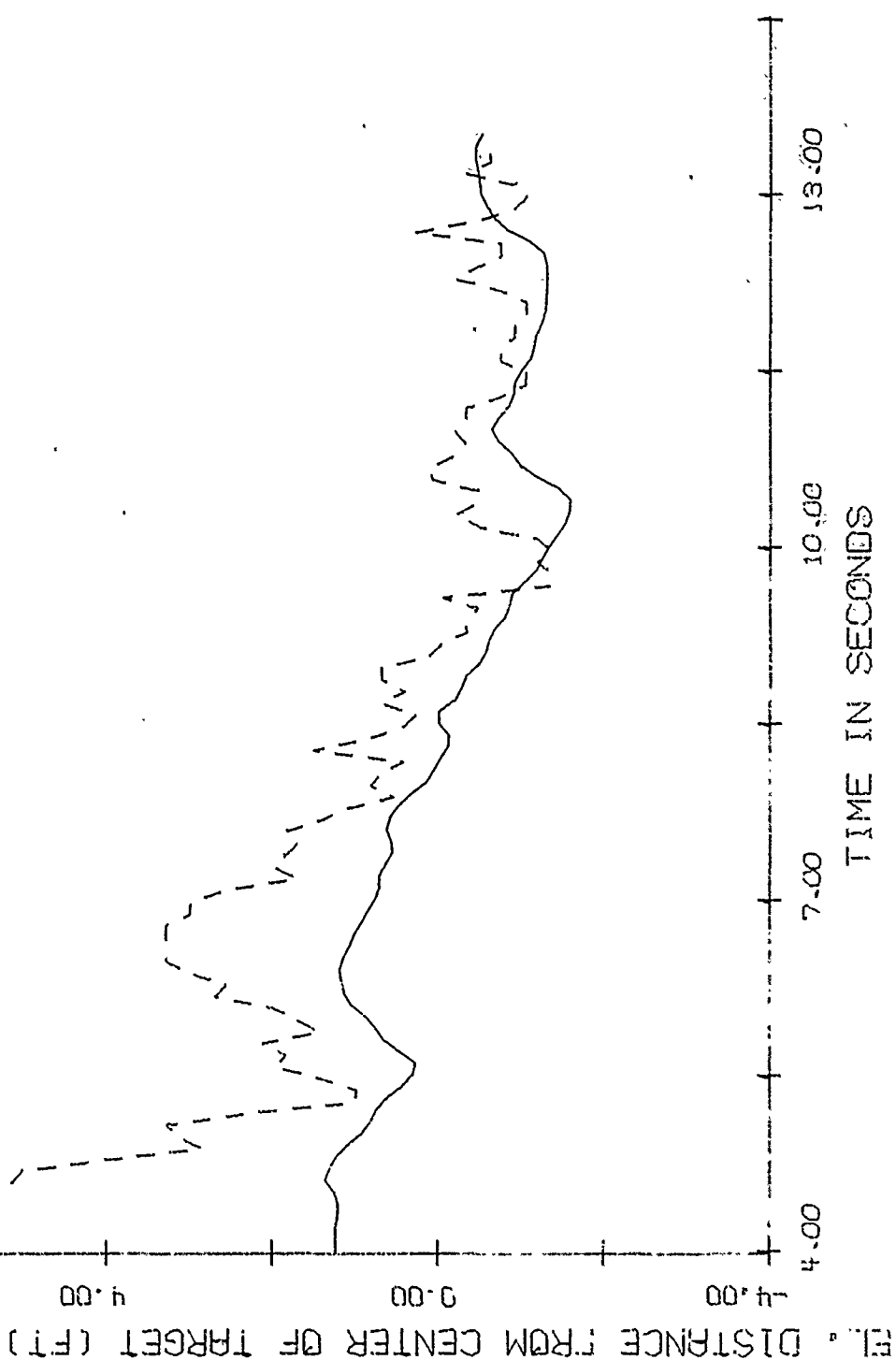
TARGET RANGE - 2855 METERS
TRIAL NO. 2438

— SIMULATION
- - - LIVEFIRE



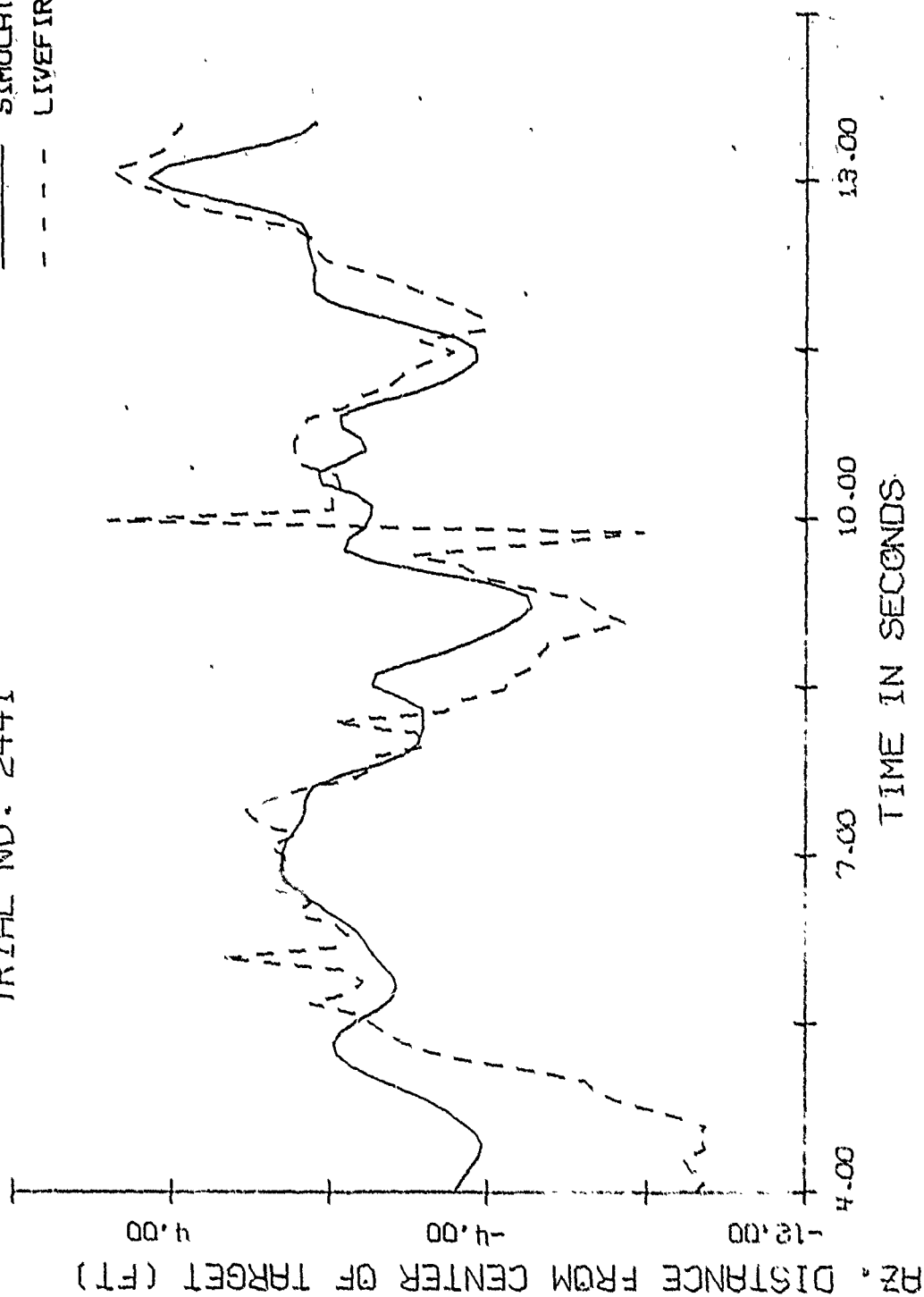
TARGET RANGE - 2855 METERS
TRIAL NO. 2441

— SIMULATION
- - - LIVEFIRE



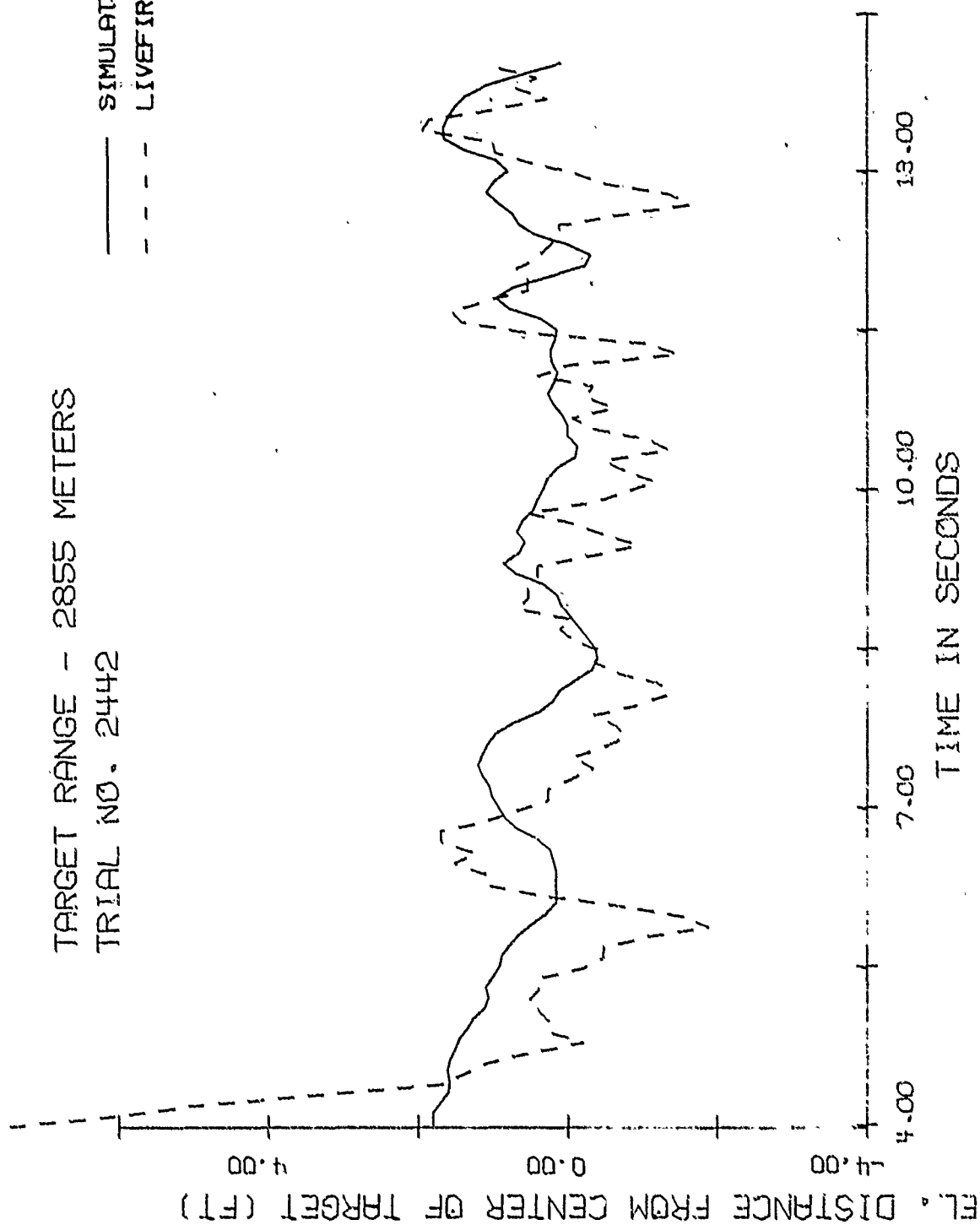
TARGET RANGE - 2855 METERS
TRIAL NO. 2441

— SIMULATION
--- LIVEFIRE



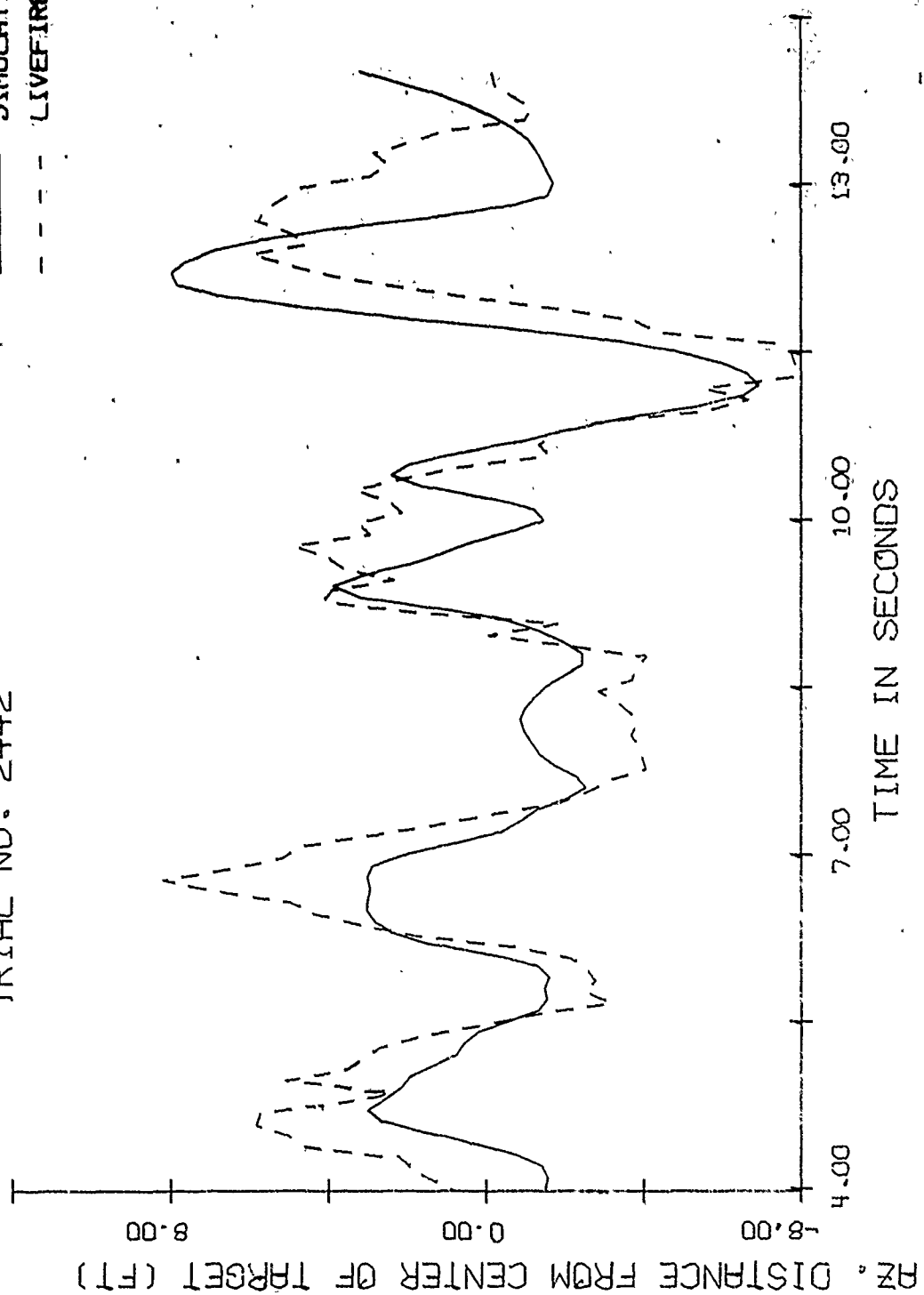
TARGET RANGE - 2855 METERS
TRIAL NO. 2442

— SIMULATION
- - - LIVEFIRE



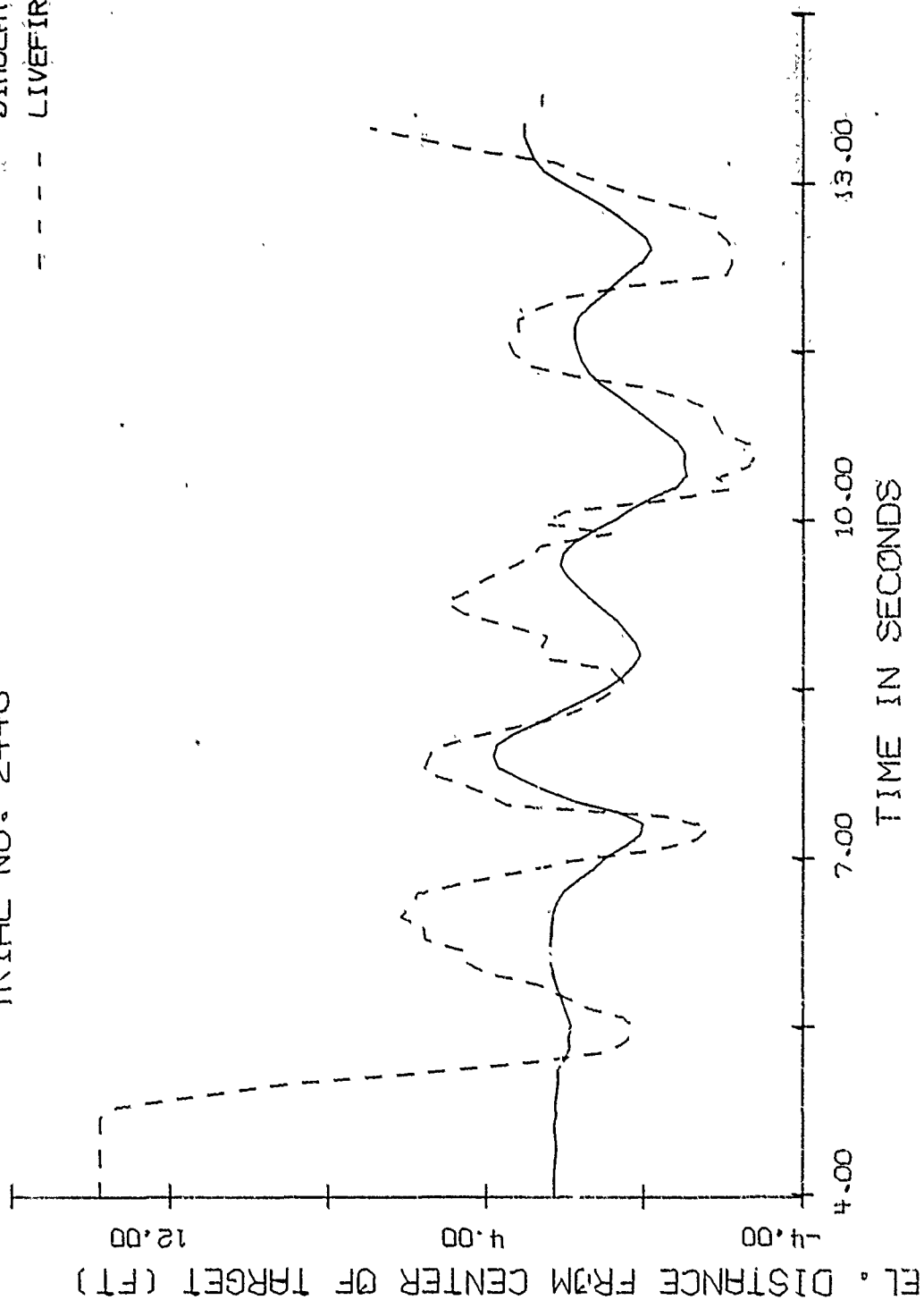
TARGET RANGE - 2855 METERS
TRIAL NO. 2442

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 2446

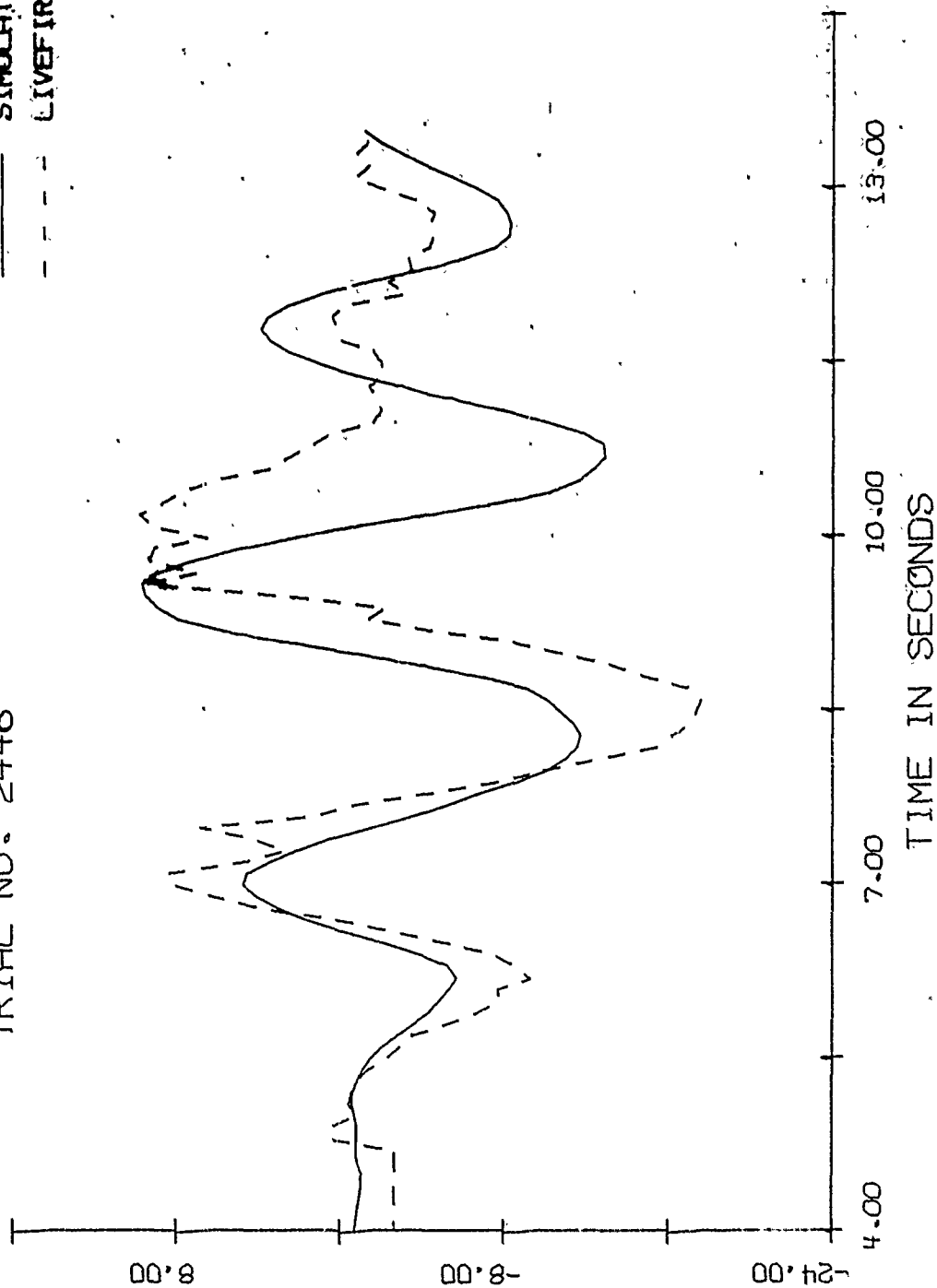
— SIMULATION
- - - LIVEFIRE

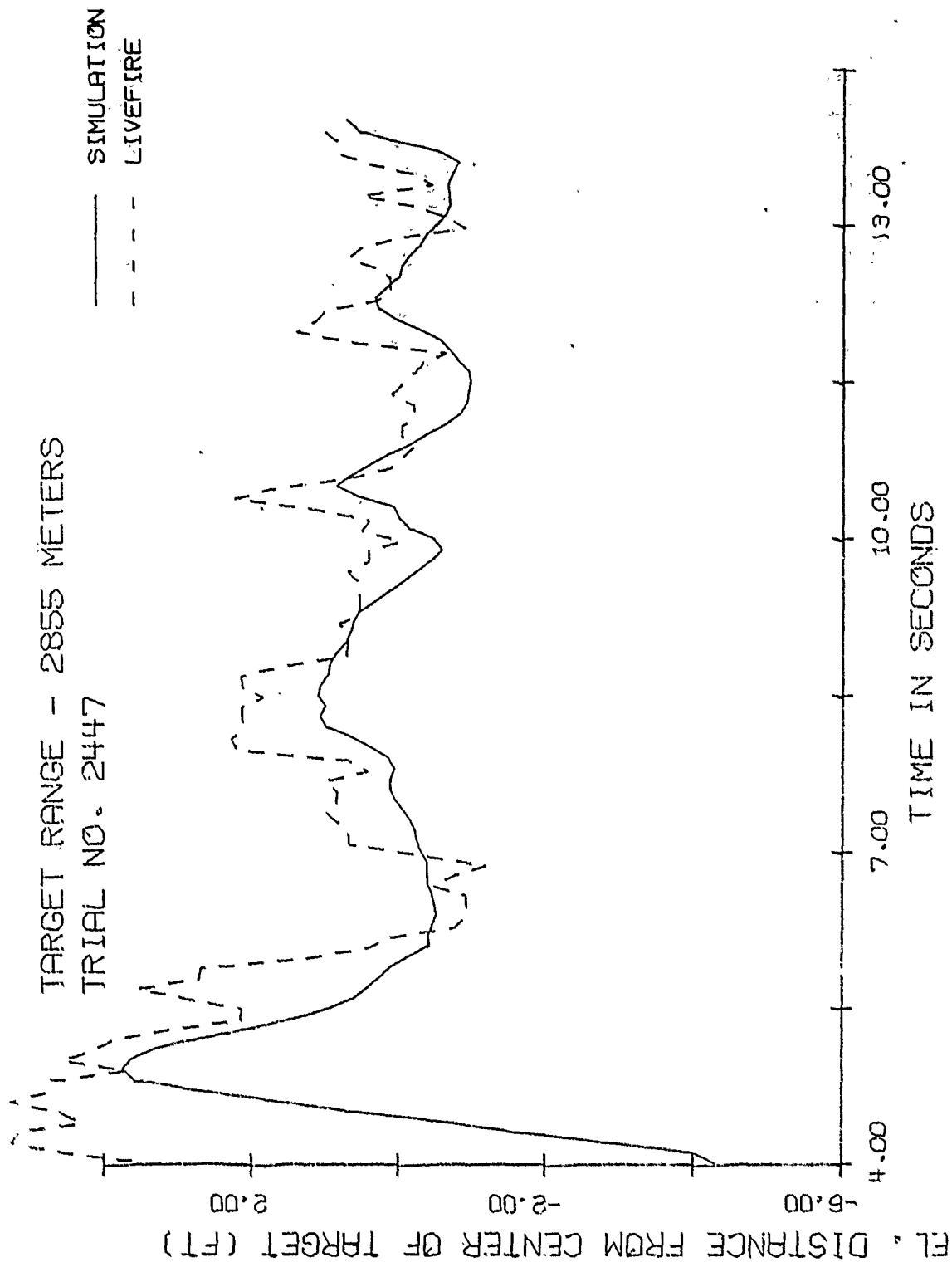


TARGET RANGE - 2855 METERS
TRIAL NO. 2446

— SIMULATION
- - - LIVEFIRE

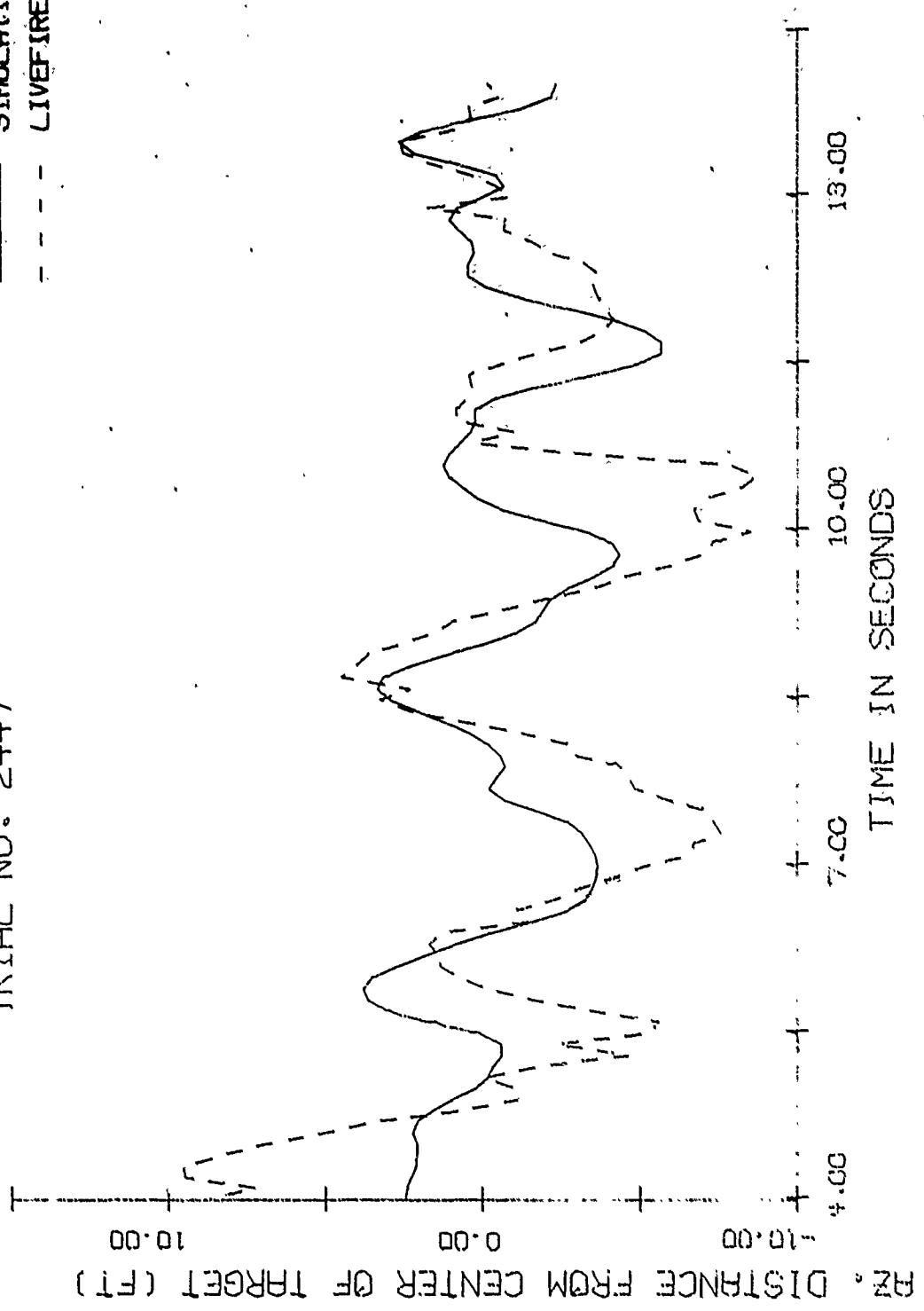
AZ. DISTANCE FROM CENTER OF TARGET (FT)





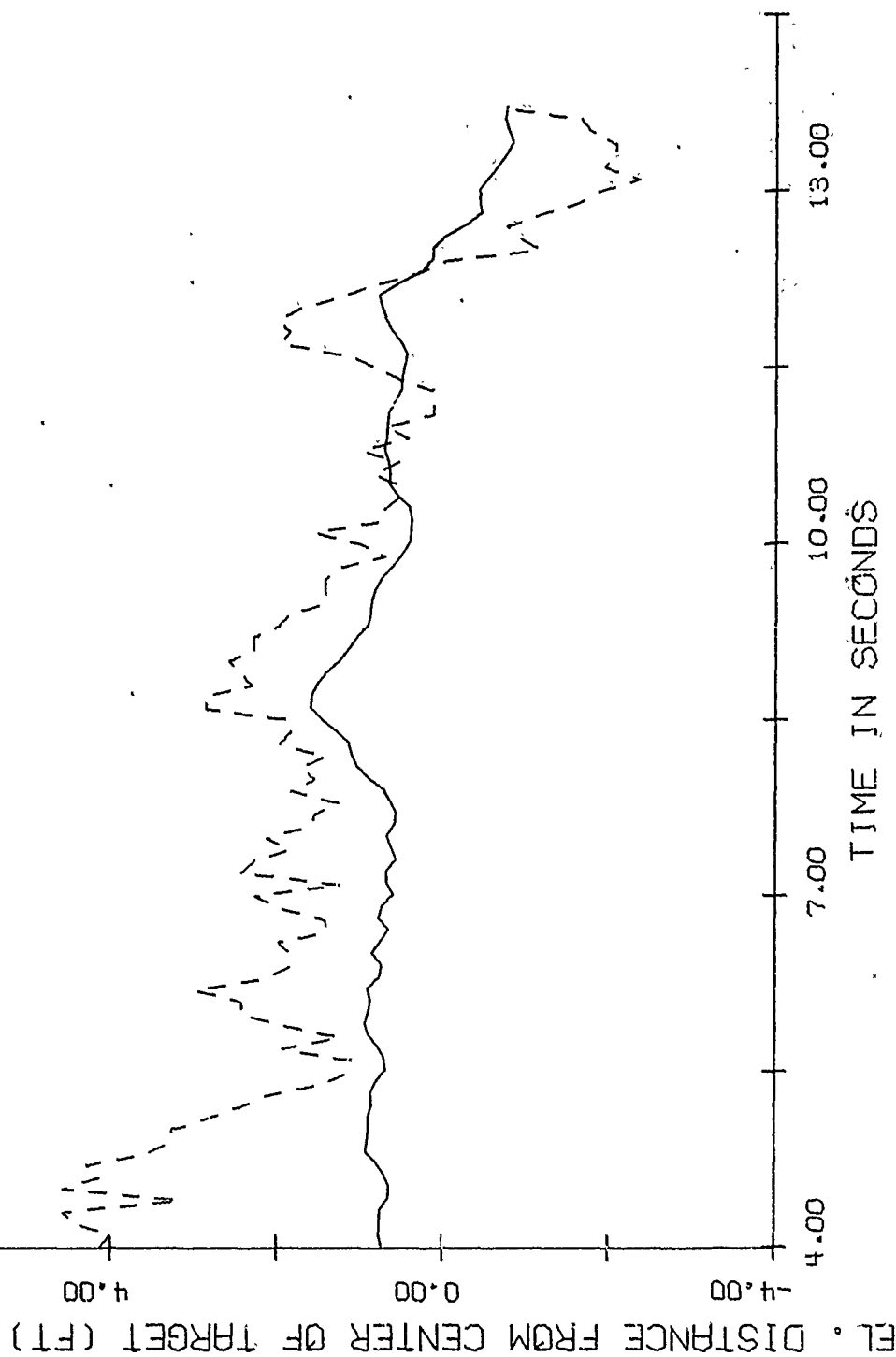
TARGET RANGE - 2855 METERS
TRIAL NO. 2447

— SIMULATION
--- LIVEFIRE



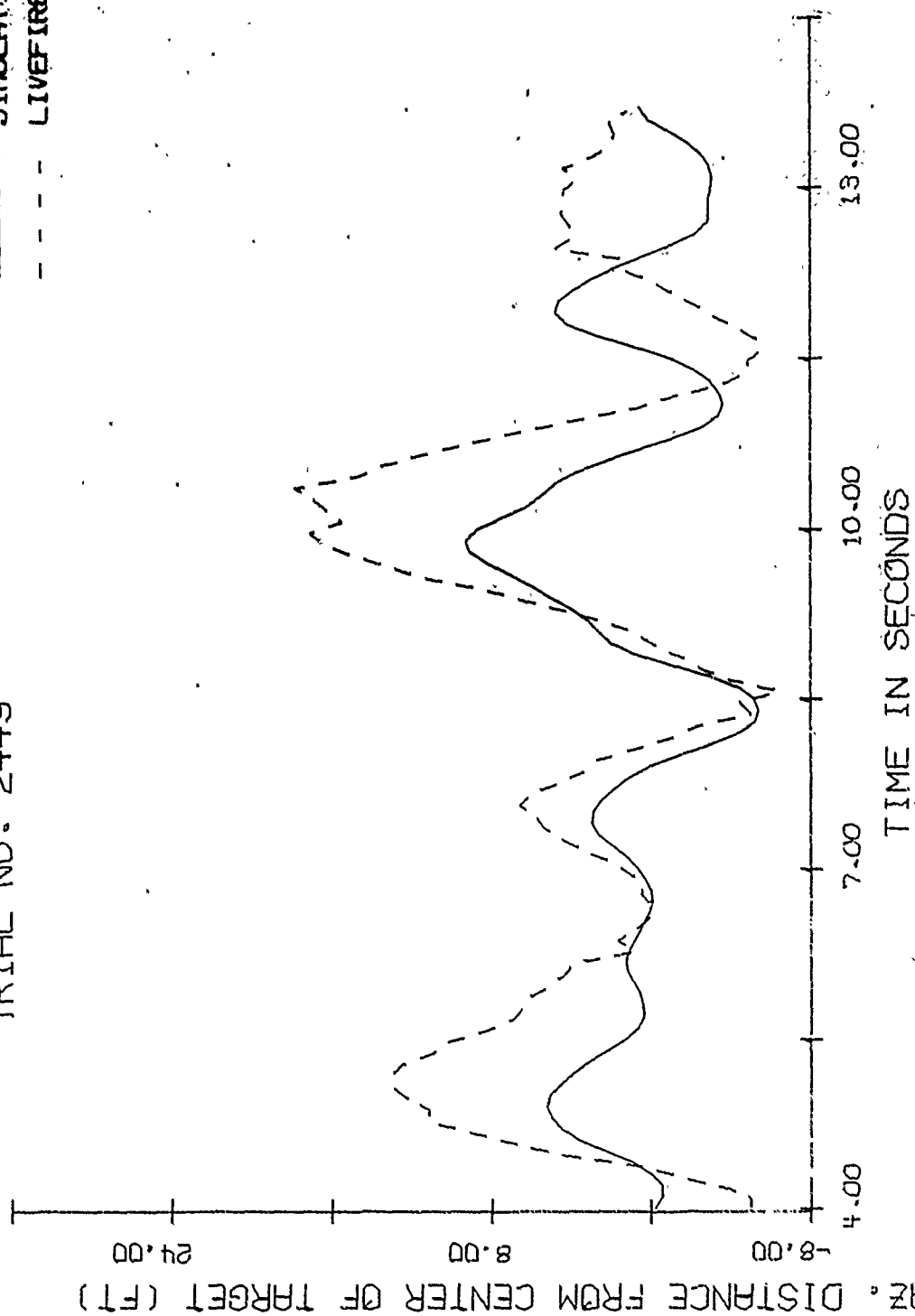
TARGET RANGE - 2855 METERS
TRIAL NO. 2449

— SIMULATION
- - - LIVEFIRE



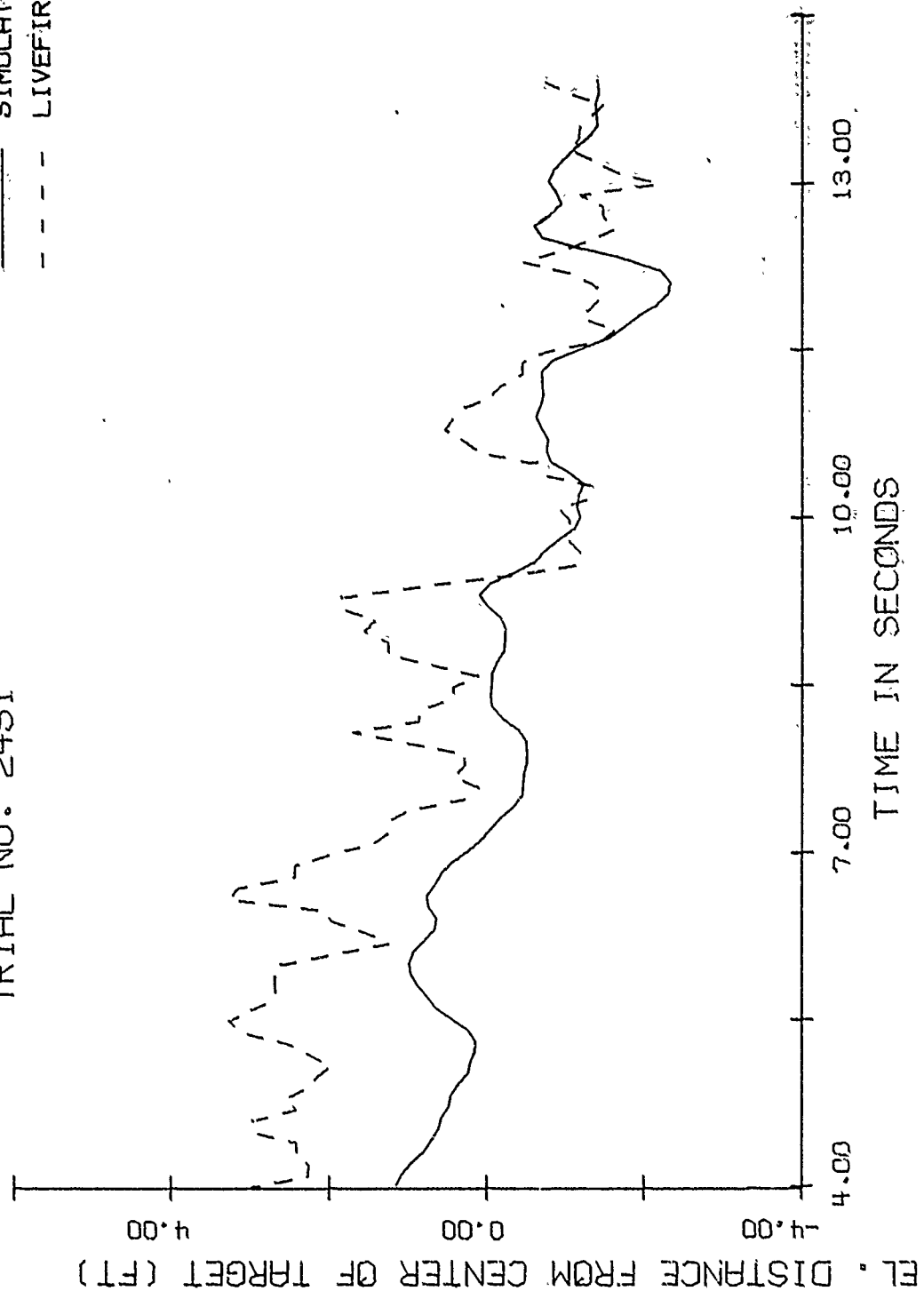
TARGET RANGE - 2855 METERS
TRIAL NO. 2449

— SIMULATION
- - - LIVEFIRE



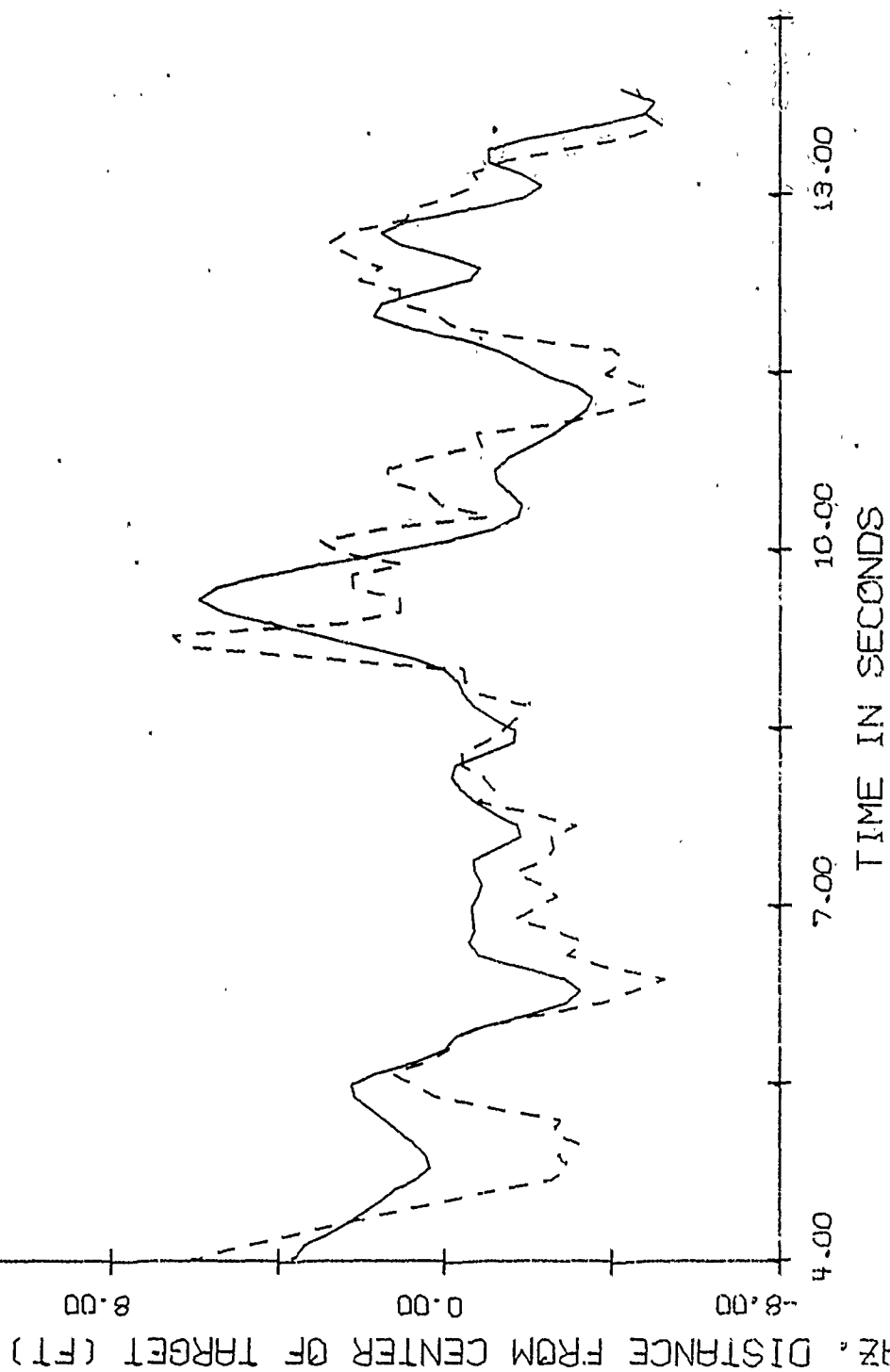
TARGET RANGE - 2855 METERS
TRIAL NO. 2451

— SIMULATION
- - - LIVEFIRE



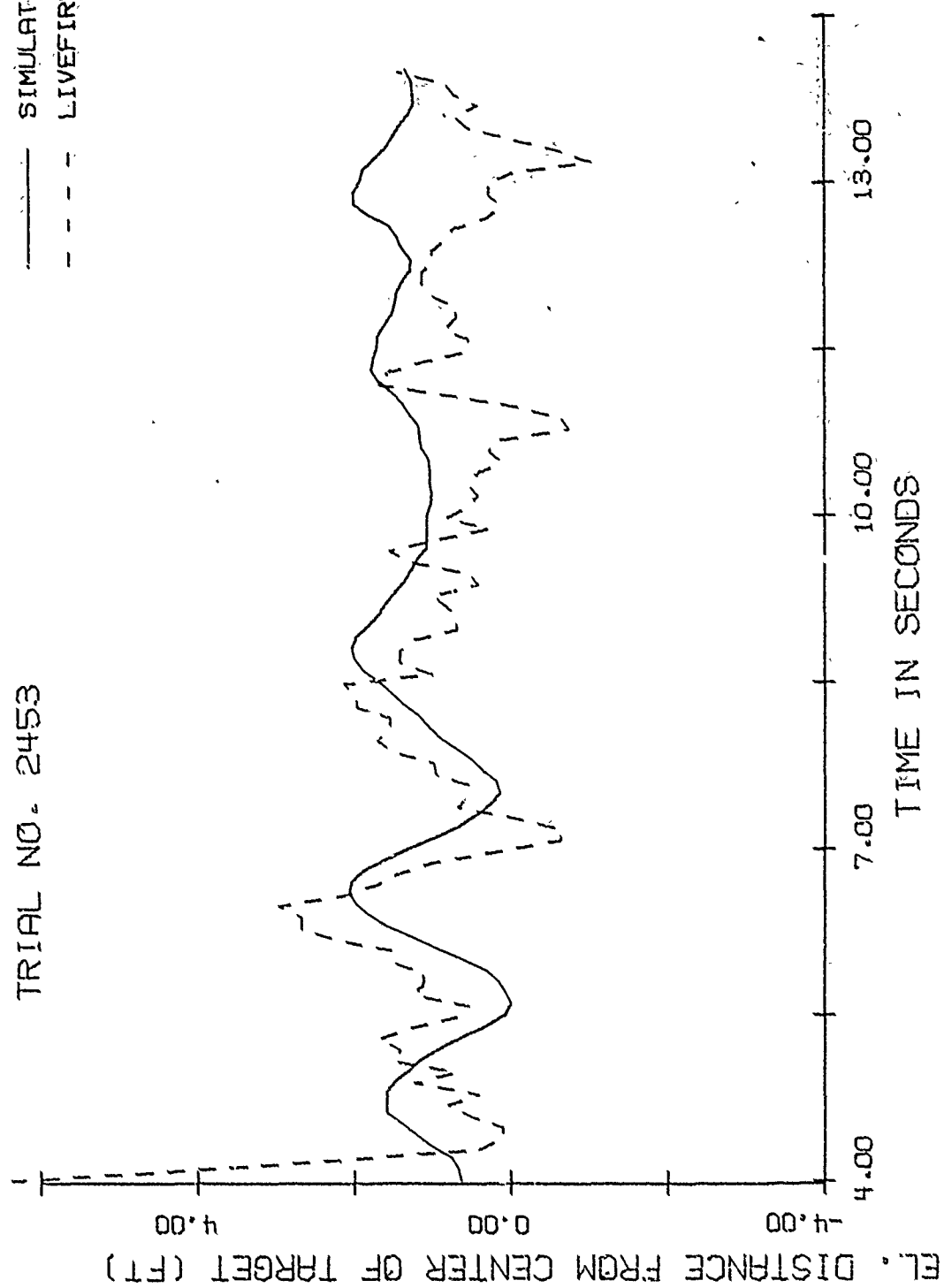
TARGET RANGE - 2855 METERS
TRIAL NO. 2451

— SIMULATION
- - - LIVEFIRE



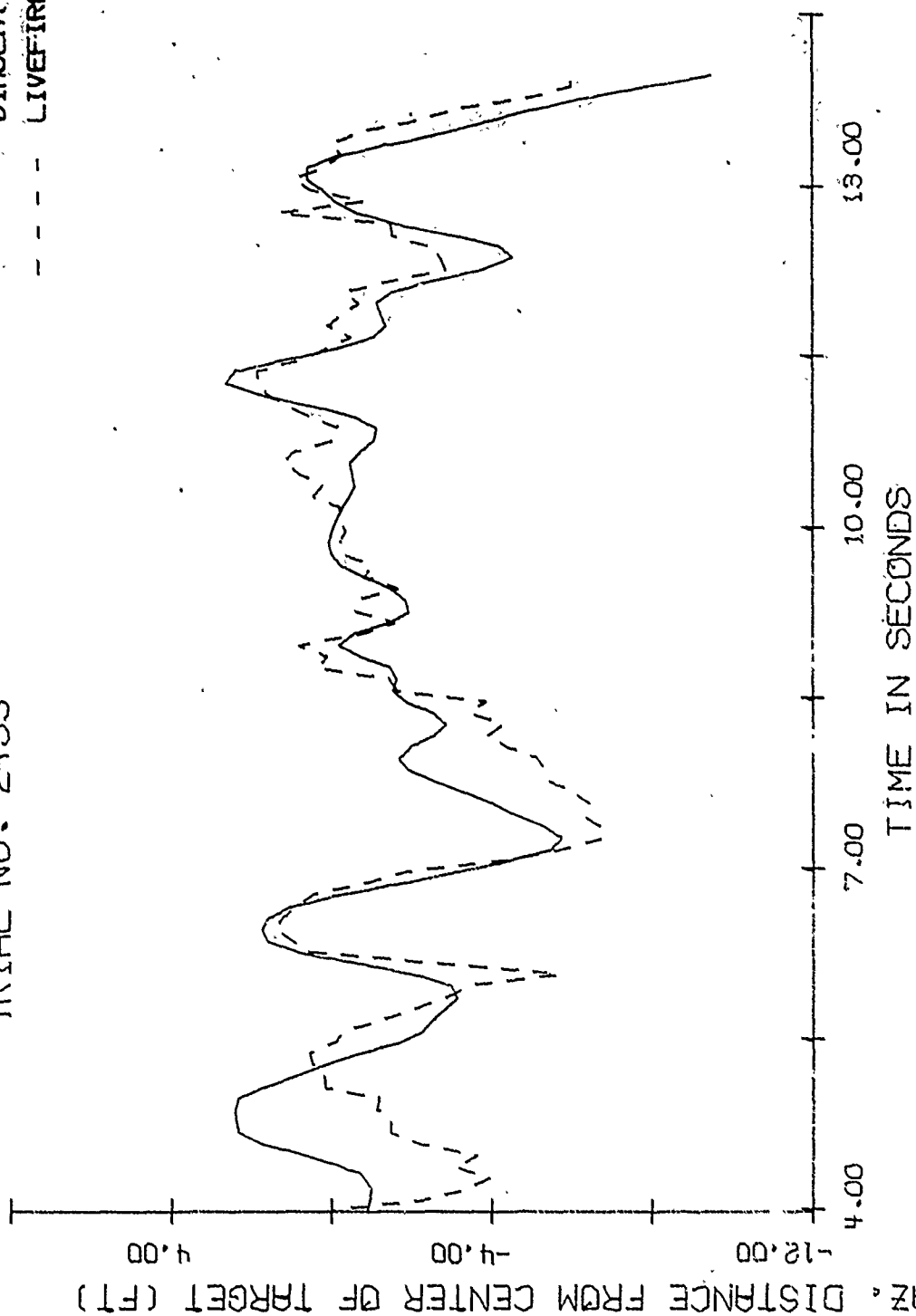
TARGET RANGE - 2855 METERS
TRIAL NO. 2453

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 2453

— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 2454

— SIMULATION
- - - LIVEFIRE

FL. DISTANCE FROM CENTER OF TARGET (FT)

13.00

10.00

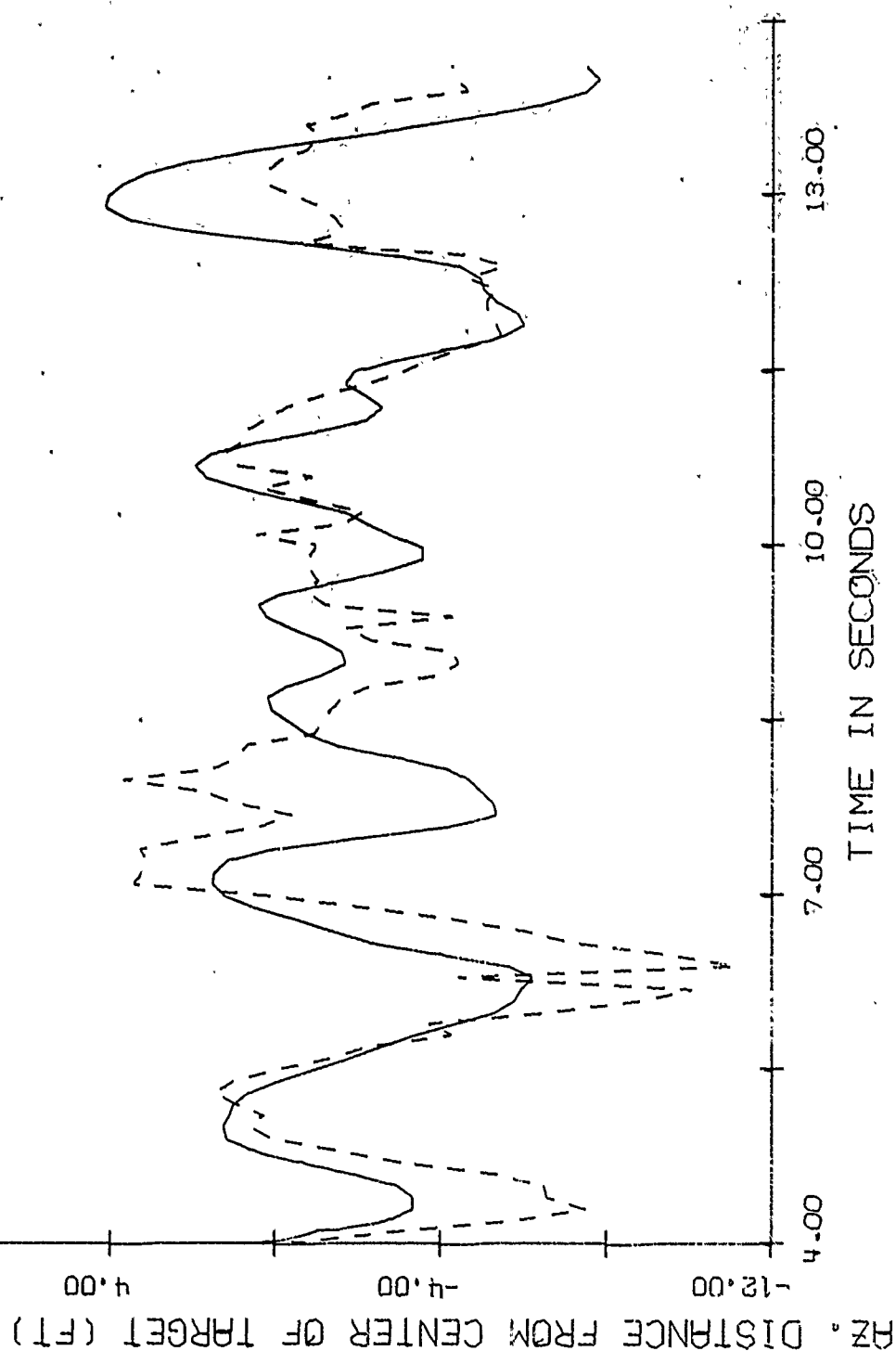
7.00

4.00

TIME IN SECONDS

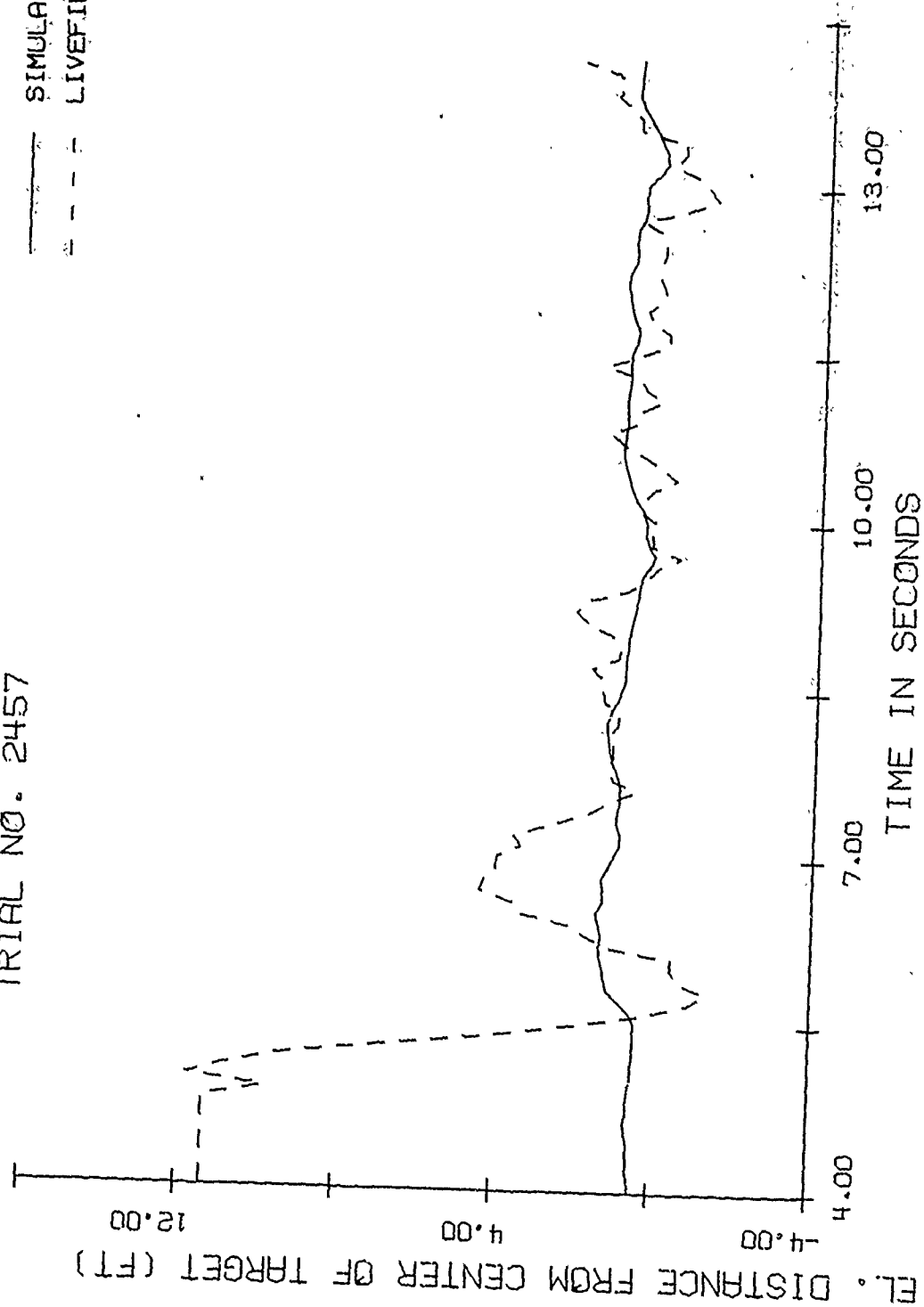
TARGET RANGE - 2855 METERS
TRIAL NO. 2454

— SIMULATION
-- LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 2457

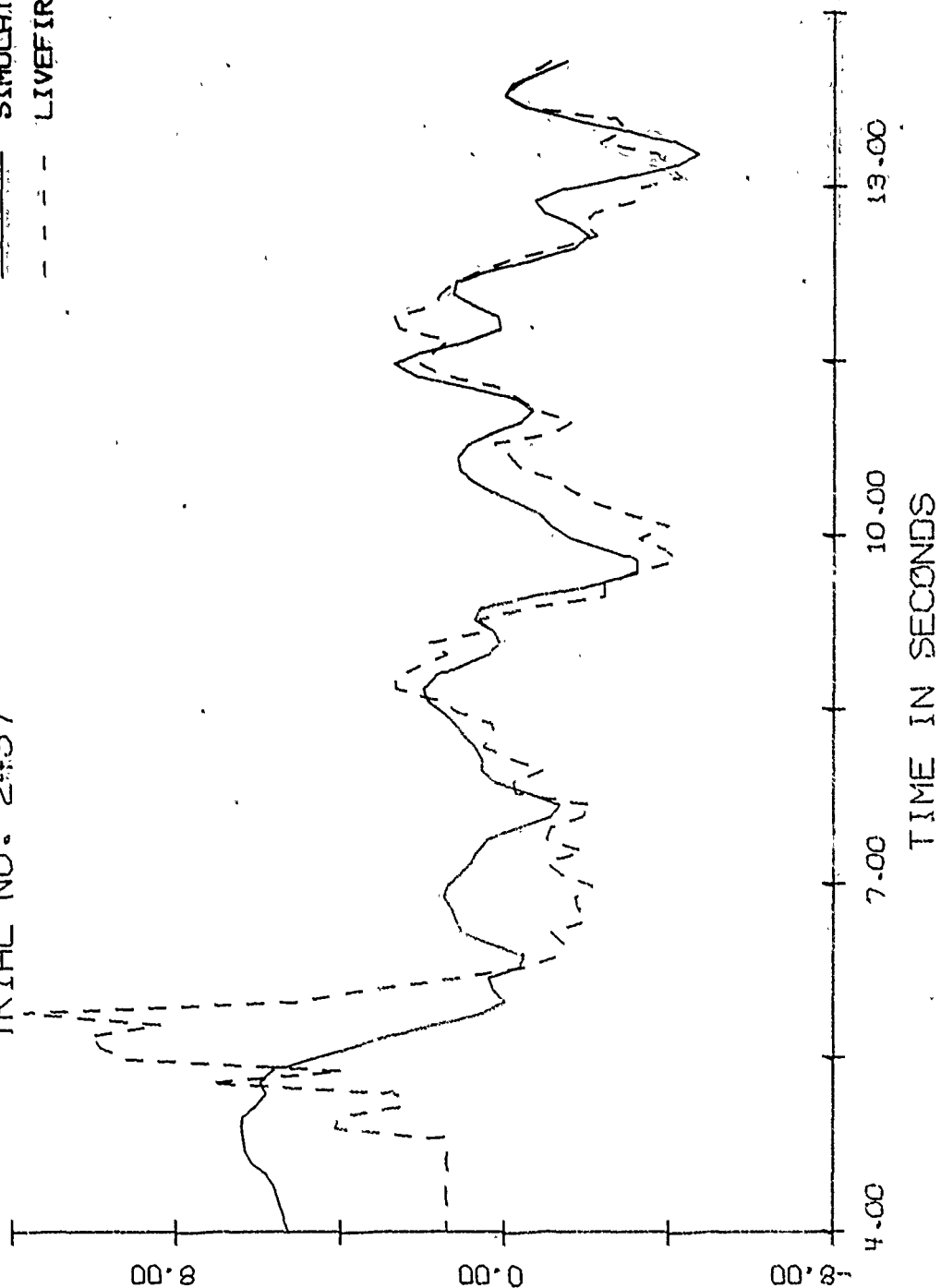
— SIMULATION
- - - LIVEFIRE



TARGET RANGE - 2855 METERS
TRIAL NO. 2457

— SIMULATION
- - - LIVEFIRE

AZ. DISTANCE FROM CENTER OF TARGET (FT)



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